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ABSTRACT

This document reviews the work of the Maryland Mathematics Commission (MMC). The mission of the MMC was to review and provide recommendations on the following critical issues, all of which have the potential to influence mathematics learning in Maryland: (1) improve achievement in mathematics at every level, in every school and school district; (2) a balanced mathematics curriculum, pre-K-12; (3) qualified teachers in all mathematics classrooms; (4) daily instructional time in mathematics for all students; (5) establish the role of technology; and (6) raise public awareness about the value of mathematics for all students. The core of the report contains background information, current status, vision, and recommendations, including their rationale for the work analyzing the key areas of achievement, curriculum, instruction, teacher quality, technology, and outreach. (KHR)

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How many wheels altogether?
What Do You Do with the Extras?
1. There are 36 people who are taking a trip in some small vans. Each van holds 8 people. How many vans will they need?
2. Eight people are going to share 36 crackers equally. How many crackers will each person get?
5+5 then add 2 you don't add 4 yet because the equal sign is first

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Keys to Math Success

A Report from the Maryland Mathematics Commission

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June 2001

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Keys to Math Success

A Report from the Maryland Mathematics Commission

June 2001

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WELCOME TO *Keys to Math Success: A Report from the Maryland Mathematics Commission*. We are very pleased to provide you with our final report. This work began in September 1999, when I was appointed to chair the Commission. Commission members were approved by the Maryland State Board of Education in October 1999. The Commission began meeting in October of 1999 and met nine times as a full commission. Commission committees met outside of full commission meetings and electronically to complete the work provided in our full report.

The mission of the Maryland Mathematics Commission was to carefully review and provide recommendations on the following critical issues, all of which have the potential to influence mathematics learning in Maryland. They are:

The need to improve achievement in mathematics at every level, in every school and school district.

The Commission reviewed Maryland student achievement data from the Maryland State Performance Assessment Program (MSPAP), the Comprehensive Test of Basic Skills (CTBS), the Third International Mathematics and Science Study (TIMSS), and the National Assessment of Educational Progress (NAEP). This analysis was closely connected to the Commission review of curriculum and instruction, with the goal of providing suggestions to improve statewide performance in mathematics.

The need for a balanced mathematics curriculum, PreK-12.

The Commission examined national and state standards for mathematics and discussed how those standards are aligned with existing curricula. One issue this report addresses is the critical role of algebra in the PreK-12 mathematics curriculum. Given the increasing number of students who enroll in algebra at the middle school level, it is imperative that elementary and early middle school students receive appropriate instruction in patterns, functions, and algebra; geometry; measurement; and probability and statistics—in addition to number and operations, the traditional base of the K-6 mathematics curriculum.

The need for qualified teachers in all mathematics classrooms.

The Commission examined how elementary, middle, and high schools are staffed. Data relative to the number of certified mathematics teachers at the middle and high school levels were reviewed and discussed. The mathematics coursework, related mathematics education coursework, and experiences required of pre-service teachers were also reviewed. A related and critically important issue is the amount and quality of professional development provided, statewide, for mathematics teachers. The commission examined the role of professional development in keeping teachers current and qualified in their subject area. This was discussed by both the Teacher Quality and Instruction committees.

The need for all students to receive daily instructional time in mathematics.

Students need time to learn mathematics and teachers need time to teach it. The Commission identified the need for a consistent block of time every day for the teaching and learning of mathematics at the early childhood, elementary, middle, and high school levels.

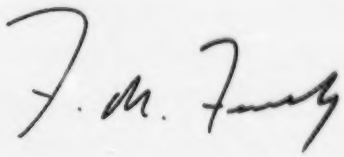
The need to establish the role of technology.

The commission examined the role of the calculator, graphing calculator, and computer technology in the classroom. Issues discussed included the use of and access to technology in mathematics instruction and learning, as well as its effect on mathematics curriculum.

The need to raise public awareness about the value of mathematics for all students.

As indicated, mathematics is an important subject—a gatekeeper. However, it must become an important subject for all children, regardless of race, ethnicity, and gender. The Commission reviewed national initiatives in mathematics which are designed to increase public awareness of the importance of mathematics and its critical role in the future of students and our country.

Statements emphasizing equity and the importance of teaching and learning mathematics frame the full report of the Maryland Mathematics Commission. The core of our report contains background, current status, vision, and recommendations, including their rationale, for our work analyzing the key areas of Achievement, Curriculum, Instruction, Teacher Quality, Technology, and Outreach. It is our hope that this report causes Maryland school board members, teachers, parents, administrators, teacher educators, mathematicians, and all those even remotely connected to the learning and use of mathematics to think seriously about all aspects of the important role of mathematics in schooling.



Francis (Skip) Fennell, Chair
Maryland Mathematics Commission
Western Maryland College
June 2001

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Acknowledgments

THIS REPORT IS DEDICATED to the children and teachers of Maryland in the hope that more students and teachers will appreciate and value mathematics. Our work would not have been possible without the tireless efforts of Ms. Donna Watts and her Maryland State Department of Education mathematics team consisting of Ms. Elaine Crawford, Ms. Linda Kaniecki, and Ms. Karen Ross. In addition, the words, wisdom, and work of the following consultants to the Maryland Mathematics Commission informed, affected, and guided our work:

- Ms. Gail Burrill, Mathematical Sciences Education Board, Washington, D.C.; Principal Investigator, *Figure This!;* Past President, National Council of Teachers of Mathematics.
- Dr. Joan Ferrini-Mundy, Associate Dean for Science and Mathematics Education, Professor of Mathematics and Teacher Education, Michigan State University; Chair, Writing Group, *Principles and Standards for School Mathematics*, National Council of Teachers of Mathematics.
- Mr. Gary Heath, Branch Chief, Arts and Sciences, Maryland State Department of Education.
- Mr. Steve Leinwand, State Coordinator of Mathematics, Connecticut; Board of Directors, National Council of Teachers of Mathematics.
- Ms. Barbara Reeves, Director, Instructional Technology Unit, Maryland State Department of Education.
- Dr. Edward Silver, Professor of Mathematics Education, University of Michigan; Chair, 6-8 Writing Group, Principles and Standards for School Mathematics.
- Dr. Harold Wenglinsky, Educational Testing Service, Princeton, New Jersey.

Special thanks to the following for their reviews of prior drafts of this work: Tom Rowan (University of Maryland, College Park), Steve Leinwand, Joan Ferrini-Mundy, and numerous Commission members.

Finally, a very special thank you and note of appreciation to Dr. Erin Smith, Assistant Professor of English at Western Maryland College, for her editorial assistance and for the design and production of this manuscript.

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The Importance of Teaching and Learning Mathematics

MATHEMATICS IS A GATEWAY and can be the key to many lifelong opportunities. It opens doors to careers and is critical for success in much of the workplace. Jobs that once required little mathematics now demand specific skills in algebra, geometry, measurement, probability, and statistics. Almost 90% of all new jobs being created require more than a high school level of mathematics. In addition, it is generally understood that 20% of the jobs today are technology based and that 80% of the jobs tomorrow will be technology based.

Mathematics is the language of technology. As technology becomes more prevalent in the workplace, workers will find they need to have a strong background in mathematics, the foundation for which will have been laid before high school. Mathematics is used to formulate, interpret, and solve problems in fields as diverse as engineering, economics, communication, business, finance, health, and ecology. It provides us with powerful theoretical and computational techniques to advance our understanding of the modern world and to develop and manage the technology industries that are the backbone of our economy.

Mathematics is vital to the national interest. Strong mathematical capability on a national scale is essential for industrial and technological leadership. A shortage of workers skilled in mathematics could affect U.S. performance and competitiveness in global markets. According to a recent report from the United States Department of Commerce Office of Technology Policy (1999), as information systems become more important to the economy, many more workers skilled in mathematics-related disciplines will be needed to maintain the United States' international competitiveness. A survey cited in the report indicates that 50% of company executives in the information technology field identify a lack of skilled workers as "the most significant barrier" to their companies' growth during the next year.

Mathematics competence is a workplace necessity and will be even more essential for higher-income jobs as the growth in technology-based jobs increases. Science, technology, and engineering jobs are among the fastest growing career areas in the U.S. workforce. If current trends persist, the U.S. may start to fall behind, lacking the much-needed talent that spurs innovation and that has produced such a strong economy and high quality of life. The following statistics outline the needs of business for skills in high technology areas:

- Between 1996 and 2006, 244,000 new engineering jobs will be created—an 18% increase.
- Over the same time period, the number of information systems positions will more than double.

- Between 1986-1996, the number of U.S. bachelor degrees awarded increased 25%, while those in engineering decreased 13%.
- Of the estimated 3.4 million information technology jobs, 10% are unfilled.
- Corporate need for information systems is growing at a rate of 25% annually.

(Roche, 1998)

For the past three years, Public Agenda's *Reality Check 2000* surveys show little change: Employers and college professors remain generally dissatisfied with the skills of young people entering jobs and higher education. These surveys generally attempt to clarify teaching and curriculum guidelines, assess the qualifications of teachers, and periodically test students to ensure progress.

The need to improve science, math, engineering, and technology education is recognized at the national level. Among other initiatives, Congressman V. Ehlers (R-MI), Vice Chairman of the House Science Committee and member of the Education and the Workforce Committee, has introduced legislation to improve science, mathematics, engineering, and technology education at the K-12 level. Highlights of the bills include instituting summer professional development programs for teachers, providing partial tax credits to pay for college tuition, and instructing teachers in the use of hands-on science and mathematics. Meetings are planned with various engineering groups to discuss pre-college science, mathematics, engineering, and technology education programs to help support this legislation.

Maryland is among the states that have launched initiatives to raise academic standards in public schools and thus increase student interest in technology careers. Currently, we face a critical shortage of trained students:

- From 1986-1996, four-year degrees in engineering were down 13%; those in information technology were down 18%.
- At the beginning of 1998 computer science majors made up only 3.1% of students, and engineering students accounted for only 4.2%.
- As many as 10,000 high-tech positions are currently unfilled in the state of Maryland (University of Maryland)
- Surveys indicate that more than 60% of Maryland businesses expect their need for workers with technical knowledge and experience to increase.

(Roche, 1998)

While Maryland has been successful in establishing an exemplary state performance-based assessment program, students have not been able to meet the anticipated levels of

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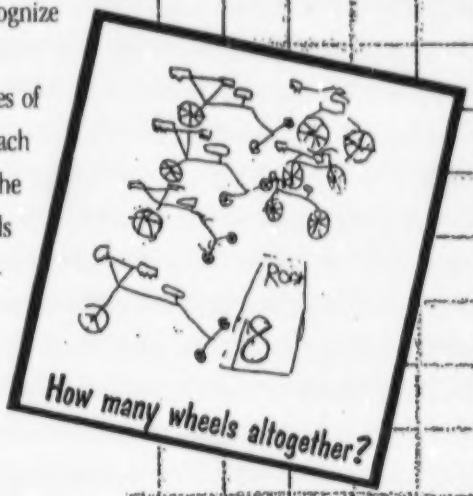
satisfactory performance. Presently the state-mandated tests include the Maryland State Performance Assessment Program (MSPAP), the Maryland Functional Tests, and the Comprehensive Test of Basic Skills (CTBS/5). The High School Assessments (HSA) are projected as a graduation requirement for 2005. According to the latest published results of the MSPAP (2000), the percentage of eighth-grade Maryland students scoring at a satisfactory level was 50.4%, an increase of 14.6% since the tests began in 1993. Statewide, the performance gap between black students and white students continues to be large. Fewer than 25% (24.7) of Maryland's African American students achieved a satisfactory rating on the mathematics portion of the eighth grade MSPAP. While Maryland has made progress, we recognize that we are not where we want to be.



The MSPAP is a measure of the effectiveness of schools, not the abilities of individual students, and the results vary widely by school system and within each school system. Each year, there are several schools in Maryland that achieve the benchmark score of a 70% success rate. In 2000, 86 of 822 (10.46%) schools reached the benchmark score or satisfactory level in third grade MSPAP mathematics. At the fifth-grade level, 138 of 822 (16.78%) schools reached the satisfactory level in mathematics. At the eighth-grade level, 49 of 228 (21%) schools reached the satisfactory level in mathematics. Currently, the success factors of such schools are not thoroughly researched or adequately used by other school systems in Maryland.

Due to the autonomy of local school systems, the mathematics curriculum and the type of mathematics instruction also varies widely. The Maryland State Department of Education has developed content standards for mathematics instruction in order to establish a framework for "bands" of grade levels. These standards have recently been defined for each grade level (Draft version, 2001). Implementation of the standards is not centralized or coordinated among the various school systems; each school system is allowed to run its own "show." While the state offers only informal guidelines for standards implementation, it encourages the sharing of best practices. In addition, depending on the school system, mathematics may or may not have top priority. The time dedicated to mathematics instruction, the qualifications of the teacher, and the level of teacher training is inconsistent between school systems and among schools within systems.

While it is widely recognized that technology enhances a student's learning when it is applied appropriately, Maryland school systems have varied access to computers and calculators and an uneven approach to professional development for the use of such technology. Maryland has recognized this disparity by establishing standards for the use of tools and

technology. The criteria are outlined in the *Maryland Plan for Technology in Education (1999-2003)* (MSDE, 1999e).

Maryland has a critical shortage of certified mathematics teachers. Only 65 mathematics teachers were prepared in Maryland during 1998-99. In order to meet this shortage, an unfortunate trend has been to hire uncertified teachers. The state must explore alternative approaches to solving this problem. In fact, it is time for boards of education at every level to consider salary inducements for mathematics teachers. Higher salaries may be achieved by extending the school year so that all teachers are responsible for a 200-day school year or work for 10 months rather than 9. We need to find creative ways to entice and keep our best and brightest mathematics teachers.

Although mathematics is recognized as an important subject at the elementary school level, it takes a backseat to reading and language arts in terms of emphasis, perceived importance, the number of minutes of instruction provided (per day and per week), and the time of the day in which it is taught. We have known for many years that negative attitudes toward mathematics first appear in the later years of elementary school (Felker, 1974). Such attitude problems often intensify through the middle school years and may lead to the development of mathematics anxiety. Maryland needs a plan to emphasize the importance of mathematics for all students. This plan should consist of a way to help schools, families, students, and teachers provide experiences that will help students and their families recognize the value of mathematics—within and beyond the classroom.

Mathematics is critically important to the success of today's students. Not only is it central to the disciplines of science, engineering, and medicine, but in today's world of high technology and computers, an understanding of mathematics is needed for just about any field imaginable. Such skills are essential for the long-term vitality of the U.S. in global and domestic markets.

A Statement on Equity

As the Maryland Mathematics Commission studied mathematics teaching and learning issues, we continued to encounter problems related to equity. The work of the Commission had to address the issue of equity because it is so critical to all of the recommendations.

The Commission's premise is that all students must have the opportunity to learn mathematics. Educational equity is central to this goal. This means that every student — regardless of his or her personal characteristics or background — must have not only the opportunity, but the support needed to learn mathematics. No student should be denied access to such learning opportunities because of cultural differences, socio-economic status, or developmental delays in maturation. However, this does not, in any way, suggest that "one size fits all" when it comes to curriculum and instruction. Rather, it demands that "reasonable and appropriate accommodations be made as needed to promote access and attainment for all students" (NCTM, 2000, p. 12).

In a mathematics report card published over 13 years ago (Dossey, et al, 1988), it was noted that only half of the 17 year olds in this country could solve mathematics problems at the middle school level: "Those who performed the worst tended to be minority students attending schools in low income urban neighborhoods and girls across the socioeconomic spectrum. Both groups systematically scored lower on mathematics tests and took far less challenging mathematics courses than did middle class white boys" (Ross, 1999, p. 2).

Have things changed? Well, yes and no. Efforts by the National Council of Teachers of Mathematics, and the Mathematical Association of America led to standards in mathematics curriculum, teaching, and assessment (NCTM, 2000, 1995, 1991, 1989; MAA, 1991). States have followed this national initiative. Projects supported by the National Science Foundation and the Ford Foundation have attempted to close the gap between minority and non-minority students. These initiatives have targeted rural and urban areas of our country. At the core of such work is the fundamental belief that all children can learn mathematics, including higher level mathematics, and that how we teach mathematics affects the learning of this very important subject.

However, the *Minority Achievement in Maryland Report* (MSDE, 1998a) portrays a state where African American and white students achieve quite differently. Male and female African American students score significantly lower than their white counterparts at every grade level measured on the Comprehensive Test of Basic Skills/5 (CTBS/5), the Maryland State Performance Assessment Program (MSPAP), and on ETS's SAT. One encouraging statistic among those presented in the next section on Achievement indicates that all females

are doing as well or better than male students on all of the aforementioned measures with the exception of the SAT.

Equity was a fundamental issue and concern for each of the committees that have worked toward the completion of *Keys to Math Success*. Too many schools and school systems in this country support the belief that only some students can learn mathematics. Mathematics is not a subject for "nerds" only. It is a subject that must be for everyone. We know that the more mathematics students complete the better their chances for opportunities, ranging from higher education to careers. Low expectations are simply not an option. Expectations for all students need to be raised: "All students should have access to an excellent and equitable mathematics program that provides solid support for their learning and is responsive to their prior knowledge, intellectual strengths, and personal interests" (NCTM, 2000, p. 13). While high expectations are necessary, access to such programs should not be assumed.

It is true that some students need more time than others on particular mathematics topics. It is also true that the access to specific resources that foster the success of students may be more of an issue in areas of extreme poverty than in other areas. In short, it is worse than unfair to have high expectations without recognizing the need for accommodating differences and providing resources and support for all classrooms and students. Achieving equity is not easy. It requires a significant allocation of resources, both material and human, in schools and classrooms in Maryland. Curriculum materials, supplementary materials, technological tools, and the consistent, continuing development of classroom teachers are all ingredients in this equation.

Equity is a crucial factor in all of the recommendations within *Keys to Math Success*. As the state, local communities, and educators consider the implications of this report, it is our hope that the requirements for excellence in mathematics will begin with the understanding of these differences and the commitment to providing resources and support that will accommodate all students. This commitment must be considered an ongoing prerequisite to any of the recommendations found in these pages.

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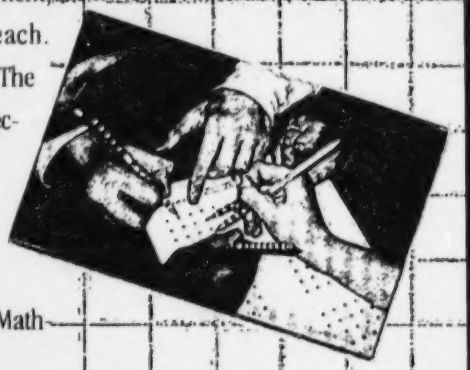
Executive Summary

THE MARYLAND MATHEMATICS COMMISSION investigated Achievement, Curriculum, Instruction, Teacher Quality, Technology and Outreach. Committees in each of these areas produced reports and recommendations. The Commission recommendations are listed below and also at the conclusion of each section of the *Keys to Math Success* report, where they appear along with their rationale.



Recommendations

To address statewide issues related to mathematics teaching and learning, the Maryland Mathematics Commission recommends the following :

1. Compile and disaggregate the results of all compulsory state assessments in terms of longitudinal cohort student test data within the state and within local school systems.

   Responsibility: *Maryland State Department of Education*

2. Identify and disseminate the successful policies and practices of those schools and school systems with high student achievement in mathematics as well as minimal differential achievement. The policies and practices should include those pertaining to instruction, assessment, and professional development.

   Responsibility: *Maryland State Department of Education and local school systems*

3. Assist local school systems in their efforts to (a) regularly assess the progress and achievement of individual students in grades 1 through 8 in light of the *Maryland Mathematics Content Standards*; (b) identify students in grades 1 through 8 who are struggling to meet the mathematics standards; and (c) provide those students with the support they will need to achieve on a regular basis within and/or outside the school day.

   Responsibility: *Local school systems, the Maryland State Department of Education, the Maryland State Legislature, and Maryland Colleges and Universities*

4. Eliminate use of the Maryland Functional Mathematics Test (MFMT) as a high school graduation requirement and support implementation of the High School Assessments (HSA).

   Responsibility: *Maryland State Department of Education*

5. Ensure that all Maryland students have access to a challenging and inviting mathematics program.

Responsibility: *Local school systems and the Maryland State Department of Education*

6. Offer guidance about ways for local school systems to focus instruction on key topics at each grade level as they implement the *Maryland Mathematics Content Standards*.

Responsibility: *Maryland State Department of Education*

7. Align state and local school system assessment programs with the content goals recommended by the *Maryland Mathematics Content Standards*.

Responsibility: *Maryland State Department of Education and local school systems*

8. Ensure that all State initiatives involving early childhood education (pre-kindergarten and kindergarten) include attention to providing appropriate mathematical experiences.

Responsibility: *Maryland State Department of Education, local school systems, and community-maintained early childhood education programs*

9. Ensure that algebraic concepts and skills are developed throughout the K-12 mathematics curriculum.

Responsibility: *Local school systems and the Maryland State Department of Education*

10. Review the *Maryland Mathematics Content Standards* periodically to guarantee that they reflect the priorities and opportunities made possible by developments in calculator and computer technology.

Responsibility: *Maryland State Department of Education*

11. Require that all students study mathematics each year of high school. Encourage local school districts to develop high quality high school courses that provide appropriate and attractive options for students with different mathematical goals, interests, and aptitudes.

Responsibility: *Local school systems and the Maryland State Department of Education*

12 Support teachers' efforts in meeting the expectation that they will provide instruction that facilitates mathematical proficiency—factual knowledge, procedural fluency, and conceptual understanding.

Responsibility: *Local school systems*

13 Provide teachers with opportunities to develop a repertoire of teaching strategies which will provide students with opportunities to become competent problem solvers and critical thinkers, and enable them to construct meaning for important mathematical ideas.

Responsibility: *Local school systems*

14 Support the expectation that teachers will continuously use varied strategies in order to monitor, enhance, and assess student learning.

Responsibility: *Local school systems*

15 Ensure that all elementary and secondary students receive one hour of mathematics instruction per day. Students in half-day and prekindergarten programs must receive a minimum of 90 hours of mathematics instruction per year.

Responsibility: *Local school systems*

16 Require pre-service early childhood, elementary and special education teachers to successfully complete mathematics and mathematics education coursework that reflects the content areas and topics suggested by the *Mathematical Education of Teachers* (CBMS, 2001).

Responsibility: *Maryland State Department of Education*

17 Establish an elementary mathematics specialist certificate.

Responsibility: *Maryland State Department of Education*

18 Establish a teaching certificate in middle school mathematics.

Responsibility: *Maryland State Department of Education*

19 Provide all teachers of mathematics with regularly scheduled, meaningful professional development opportunities in mathematics and mathematics education.

Responsibility: *Local school systems, the Maryland State Department of Education, and Maryland Colleges and Universities*

20 Ensure that all mathematics students have appropriate access to calculators, computers and internet connections for class work and homework. Teachers shall incorporate the use of such technology into the delivery of mathematics instruction.

Responsibility: *Local school systems*

21 Require that candidates for initial and permanent certification as school administrators and (K-16) mathematics teachers demonstrate computer, calculator, and Internet skills and have the ability and willingness to incorporate technology/multimedia into mathematics instruction.

Responsibility: *Maryland Colleges and Universities and the Maryland State Department of Education*

22 Collaborate with communities and businesses to support lifelong mathematics literacy.

Responsibility: *Local school systems, the Maryland State Department of Education, the Business Roundtable, Maryland Colleges and Universities, Maryland Partnership for Teaching and Learning K-12, and the Maryland Council of Teachers of Mathematics*

23 Provide opportunities to enlist the support of parents to help advocate mathematics learning.

Responsibility: *Local school systems*

24 Regularly update principals and counselors on the importance and value of mathematics for all students at every level of instruction.

Responsibility: *Local school systems, the Maryland State Department of Education, and the Maryland Council of Teachers of Mathematics*

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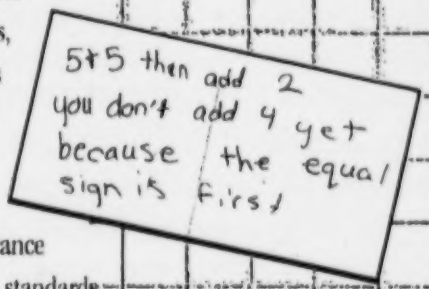
Achievement Curriculum *Instruction*
Technology Teacher Quality Outreach

Keys to Math Success

Background

As we enter the twenty-first century, efforts to increase academic achievement in mathematics have become a national focus. Across Maryland, different people ask different questions about student mathematics achievement. Business leaders, government officials, educators, and concerned citizens want to know if students have reached the goals established for Maryland. Parents of elementary school students want to know if their children have a firm grasp of skills involving number and operations. Parents of high school students ask whether their children are learning the mathematics they will need in order to succeed on college entrance tests and in college courses. Educators want to know if students have met the standards established by their local, school board-approved mathematics curriculum.



A wide variety of national, state, and local assessments provide important information about the achievement of kindergarten through twelfth-grade students in Maryland. Presently, the state-mandated tests include the Maryland State Performance Assessment Program (MSPAP), the Maryland Functional Tests, and the norm-referenced Comprehensive Test of Basic Skills (CTBS/5). The MSPAP matches the state curriculum standards. It is administered in third, fifth, and eighth grades, providing a measure of a school's level of achievement. The CTBS/5 is one of five nationally normed, standardized achievement tests given in school districts around the country. In Maryland, it is administered to students in second, fourth, and sixth grades, providing a measure of individual student achievement.[1] The Maryland Functional Mathematics Test (MFMT) addresses basic skills in mathematics and is currently a requirement for high school graduation. It is administered for the first time at the middle school level. In addition to these compulsory tests, in some Maryland school systems a random sample of students also completes the National Assessment of Educational Progress (NAEP), an assessment that examines achievement across the nation and permits state-by-state comparisons. Further, college-intending students typically take the SAT and many also take Advanced Placement examinations. A more detailed discussion of tests administered to Maryland students is presented in Appendix A.

All students are required to study algebraic and geometric concepts as a condition for high school graduation. The State is currently developing two tests to evaluate mathematics achievement in the high school. The first one will focus on algebra and data analysis, while

[1] The CTBS/5 was administered as a required assessment in Maryland for the first time in March 2000. No achievement scores reflecting administration to all Maryland students in Grades 2, 4, and 6 are available as CTBS/5 data in Maryland are only aggregated by and reported to local school systems. Thus, this data will not be discussed.

the second will focus on geometry. These tests will measure student progress toward meeting the state's Mathematics Core Learning Goals in the High School Assessments (HSA). In the meantime, enrollment trends in more advanced mathematics courses provide information about higher levels of student achievement.

What students already know and understand about mathematics influences what they will learn (Hiebert & Carpenter, 1992). Mathematics achievement in elementary school is positively related to mathematics achievement in high school. Furthermore, students who are successful in mathematics prior to secondary school and who then subsequently complete more mathematics courses in high school have similar mathematics achievement gains, regardless of their ethnic-racial identity and their socio-economic status (Tate, 1997). Thus, opportunity to learn challenging mathematics is a critical factor affecting mathematics achievement. However, simply raising graduation standards or increasing high school mathematics course requirements will be ineffective unless accompanied by systemic efforts to improve elementary and middle-school mathematics instruction and achievement.

Current Status

BECAUSE THE MSPAP was first administered in 1993, this report uses that year as the basis for examining growth in mathematics achievement. Two distinct trends are evident in this data. First, achievement as measured on the MSPAP and the MFMT has steadily improved over the last eight years (Maryland State Department of Education [MSDE], 2000). Second, an examination of the MSPAP test scores, as earned by subgroups of students, highlights disparities in achievement that persist from year to year.

Table 1. Percentage of Students Achieving a Satisfactory or Higher Rating on the MSPAP, 2000
State Goal = 70% Passing Rate

	1993	2000
Grade 3	28.6%	40.1%
Grade 5	39.5%	46.7%
Grade 8	35.8%	50.4%

Maryland State Department of Education, 2000

Across the state, the percentage of students achieving a satisfactory or higher rating in mathematics on the MSPAP has increased 11.5% for grade 3 (from 28.6% to 40.1%), 7.2% for grade 5 (from 39.5% to 46.7%), and 14.6 % for grade 8 (from 35.8% to 50.4%), which is the last grade in which the MSPAP is administered (See Table 1). While these increases are positive, this achievement falls far short of the state goal of a 70% passing rate at each grade level (MSDE, 2000).

By the end of ninth grade, more students pass the MFMT than did eight years ago (an increase from 79% to 85.1%) with 96.0% of the students in 2000 passing this test before twelfth grade. This measure was created before the current standards for high school mathematics (the Mathematics Core Learning Goals) were developed, and it does not measure current expectations for students. However, the MFMT is still administered

It may be that curriculum, instruction, and assessment for special education students emphasizes basic skills to the exclusion of conceptual understanding and problem solving.

to middle school and high school students in Maryland as a high school graduation requirement.

Despite the overall increase in passing rates on these tests, less favorable trends are evident when the 1999-2000 statewide achievement data are separated by the demographic characteristics of the students. Special education students have passing rates that are significantly lower than those of regular students; students who are African American, Hispanic, or American Indian/Alaskan Native have significantly lower passing rates than Asian/Pacific Islander or White students.

Regular students outperform special education students at each grade level tested. Moreover, the percentage of special education students whose MSPAP performance is at a satisfactory level decreases with schooling, while the percentage of regular students achieving the expected standard increases with schooling. In third grade, 41.1% of the regular students obtain a score of satisfactory or higher, as compared to 33.2% of the special education students. This difference shifts to 50.5% versus 27.6% in grade 5 and 55.5% versus 19.8% in grade 8. (See Table 2.)

Table 2. Percentage of Students Achieving a Satisfactory or Higher Rating on the MSPAP, 2000
Special Education vs. Regular Education Students

	Special Education Students	Regular Education Students	Difference
Grade 3	33.2%	41.1%	7.9%
Grade 5	27.6%	50.5%	22.9%
Grade 8	19.8%	55.5%	35.7%

Maryland State Department of Education, 2000

These MSPAP data raise serious questions about the opportunity to learn mathematics in Maryland. It may be that curriculum, instruction, and assessment for special education students emphasizes basic skills in mathematics to the exclusion of conceptual understanding and problem solving. This interpretation is based on the fact that as students progress through the grade levels, satisfactory (passing for MFMT) rates for special education students decline on the MSPAP, but increase on the MFMT. In 1999-2000, 71.7% of the ninth-grade special education students passed the MFMT (as compared to 87% of the regular education ninth graders); 92.5% of the special education students passed the MFMT by the end of eleventh grade (as compared to 96.3% of the regular education students). (See Table 3.)

Table 3. Percentage of Students Passing the MFMT, 2000
Special Education vs. Regular Education Students

	Special Education Students	Regular Education Students	Difference
Grade 9	71.7%	87.0%	15.3%
Grade 11	92.5%	96.3%	3.8%

Maryland State Department of Education, 2000

Discrepancies in performance are also evident in the MSPAP data when scores are evaluated in terms of racial/ethnic origins. White and Asian/Pacific Islander students consistently outperform American Indian/Alaskan Native, Hispanic, and African American students on the MSPAP at a statistically significant level. White and Asian/Pacific Islander students have both higher success rates and improved performance between grades 3, 5, and 8.

Hispanic and American Indian/Alaskan Native students' passing rates are lower and show less improvement from grades 3 to 8. African American students not only have significantly lower levels of performance overall, but their performance declines slightly between fifth and eighth grade as well.

Table 4. Percentage of Students Achieving a Satisfactory or Higher on the MSPAP, 2000 by Race/Ethnicity

	Grade 3	Grade 5	Grade 8
Asian/Pacific Islander	52.3%	67.5%	77.4%
White	53.9%	61.2%	65.3%
American Indian/ Alaskan Native	30.3%	38.0%	37.4%
Hispanic	28.9%	33.3%	41.6%
African American	19.5%	24.3%	24.7%

Maryland State Department of Education, 2000

These data indicate substantial differences in achievement by race and demonstrate that the State is not realizing its goal of excellence in mathematics achievement for all students.

When comparing the performance of males and females, we note a small difference in MSPAP mathematics achievement at the satisfactory level or higher in the third-grade data, with females slightly outperforming males by 2.4%. This gap widens in the fifth and eighth grade to 3.6% and 5.8%, respectively. The gender gap is even more extreme within the other content areas of the MSPAP and may reflect the influence of variables distinct from mathematical understanding. If only basic skills in mathematics are considered as on the MFMT, the gender gap for percentage of students passing in the ninth grade is only 3.6% (87% passing for females and 83.4% passing for males). The difference is even less at the conclusion of eleventh grade (99% of females versus 97.5% of males passing the MFMT). While the gender gap on the MSPAP and MFMT widens over time, the scores of both males and females increase over time.

Table 5. 2000 SAT Mathematics Mean Scores by Gender and by Race/Ethnicity

Demographic Group	Maryland	National
Gender		
Males	527	533
Females	494	498
Race/Ethnicity		
African American	421	426
Asian/Pacific Islander	574	565
White	543	530
Mexican American	511	460
Puerto Rican	500	451
Other Hispanic or Latino	489	467

Maryland State Department of Education, 2000

The MSPAP measures school performance as defined by the Maryland Learning Outcomes (MLOs). The Core Learning Goals (CLG) are extensions of the state's MLOs and are the foundation for the proposed high school graduation requirements. In the interim, the mathematics portion of the SAT provides a measure of achievement for college-intending, secondary school students. Of the 1999-2000 college-bound seniors in Maryland who took the SAT, 68% were enrolled in four or more years of mathematics, with 24% of these students enrolled in some level of calculus (College Entrance Examination Board [CEEB], 2000a).

Over the last five years, the average SAT score in mathematics for students in Maryland

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has consistently been three to five points below the national average.

has consistently been three to five points below the national average (509 versus 514 in 2000). On average, males in Maryland scored significantly higher than females on the SAT-mathematics assessment, mirroring the gender difference indicated in national data. State and national data on the SAT also reflect significant discrepancies associated with race or ethnicity (CEEB, 2000a, 2000b). (See Table 5.)

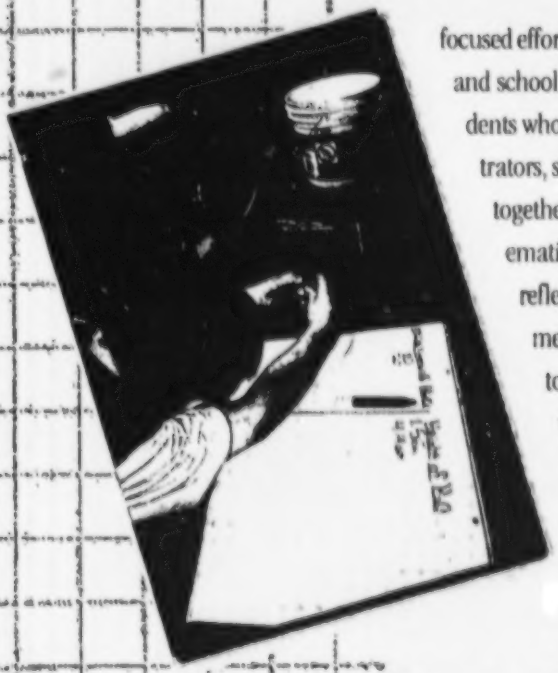
The National Assessment of Educational Progress (NAEP) in mathematics was most recently administered in 1996. At that time, Maryland did not satisfy all of the guidelines for school participation; therefore, the following results should be interpreted with caution. At both the fourth- and eighth-grade levels 1996 mathematics achievement scores of students in Maryland were comparable to that of the national average. At the fourth- and eighth-grade level, Maryland ranked twenty-ninth and twenty-fourth, respectively, out of the 44 states and jurisdictions participating in the NAEP. However, when NAEP mathematics scores from 1990 to 1996 are compared, Maryland ranks among the top five states in the nation in terms of achievement gains (Grissmer, Flanagan, Kawata, & Williamson, 2000). At the fourth-grade level, 59% of the students in Maryland scored at or above the Basic level while 22% scored at or above the Proficient level in 1996, indicating no significant change from 1992 NAEP results in Maryland. In the eighth grade, 57% of sampled Maryland students performed at or above the Basic level and 22% were at or above the Proficient level, reflecting a statistically significant increase from Maryland's 1992 NAEP results. These 1996 scores are similar to those reported in the national sample.[2]

Vision

UPON GRADUATION FROM HIGH SCHOOL, every student in Maryland should have a level of mathematics competency sufficient for entry into either the world of work or higher education. This means differential achievement due to race, gender, socio-economic status, or special education needs is unacceptable. All students must be mathematically engaged by challenging, comprehensive K-12 mathematics programs which foster each student's learning by aligning curriculum goals, instructional approaches, updated mathematics resources, professional development, in-school and out-of-school support structures, administrative leadership, and assessment measures.

The State of Maryland can eliminate differential mathematics achievement through

[2] In 1996, 62% of the national sample of fourth graders scored at or above the Basic level and 20% scored at or above the Proficient level. 61% of eighth graders performed at or above Basic level with 23% performing at or above the Proficient level (Reese et al., 1997).



focused efforts that support educational quality and educational justice within schools and school systems, particularly in those schools and school systems that serve students who live in poverty. This will occur when, in every school, teachers, administrators, students, parents, community leaders, and higher education partners work together to help students become engaged in their education and learn mathematics. The values, routines, expectations, and alliances within schools must reflect a shared vision of mathematics curriculum, instruction, and assessment (Fullan, 1998). Teachers and administrators in each school must work together as learners in a setting that incorporates on-site professional development and that consistently evaluates and refines instructional practices in light of student achievement (Newmann & Wehlage, 1996). Mathematics education is essential to the success of all students. The potential benefits of such initiatives more than justify substantial and sustained financial support.

Recommendations

To address statewide issues related to achievement in mathematics, the Maryland Mathematics Commission recommends the following :

1 **Compile and disaggregate the results of all compulsory state assessments in terms of longitudinal cohort student test data within the state and within local school systems.**

Rationale: Recently, analyses of national data addressing academic performance have considered the considerable influence of poverty on student achievement (Tate, 1997; U.S. Department of Education [USDE], 1996). Indeed, the level of school funding and percentage of child poverty have been identified as having as significant an effect on student achievement in mathematics as the level of instruction and race (Payne & Biddle, 1999). Unfortunately, separation of MSPAP data with respect to economic status is not available. Thus, it is not possible to examine the relationship between economic status and student performance on the MSPAP, nor is it possible to determine the influence of poverty on the differential

By identifying effective policies and practices we can build a knowledge base of "strategies that work" for school or system-wide implementation.

performance attributed to racial, gender, or special education status within MSPAP mathematics achievement data. Educational leaders, policy makers, teachers, the media, and parents would all benefit from assessment analyses that provide a clear picture of how students and schools are achieving. Disaggregated data will clarify the potential influences on differential achievement. The data should be analyzed to assess the effect of economic and special education status by race and gender. Longitudinal cohort data will permit school and school system examination of achievement gain or loss over time.

Responsibility: *Maryland State Department of Education*

2 **Identify and disseminate the successful policies and practices of those schools and school systems with high student achievement in mathematics as well as minimal differential achievement. The policies and practices should include those pertaining to instruction, assessment, and professional development.**

Rationale: By identifying effective policies and practices we can build a knowledge base of "strategies that work" for school or system-wide implementation. For example, NAEP state comparison data indicate that state achievement levels correlate with:

- pupil-teacher ratios in the lower grades
- participation in public prekindergarten programs
- teachers' access to resources for instruction
- teacher mobility and retention; school-based working conditions
- systemic coordination of standards, assessment, and accountability

(Grissmer, et al., 2000)

Similarly, other reports have noted that teacher preparation and continuing professional support influence student achievement (National Commission on Teaching and America's Future [NCTAF], 1997).

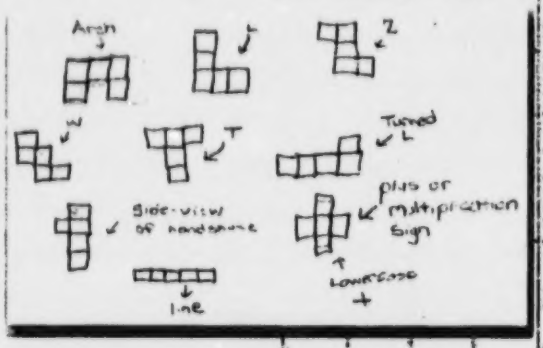
Responsibility: *Maryland State Department of Education and local school systems*

3 **Assist local school systems in their efforts to (a) regularly assess the progress and achievement of individual students in grades 1 through 8 in light of the *Maryland Mathematics Content Standards*; (b) identify students in grades 1 through 8 who are struggling to meet the mathematics standards; and (c) provide those students with the support they will need to achieve on a regular basis within and/or outside the school day.**

Rationale: Standardized testing is an important mechanism for evaluating school effectiveness and for maintaining accountability. Assessment can play a constructive role when aligned with strong standards that define the content and processes of mathematics achievement, with curricula that reflect these content and processes, and with instructional approaches that support the learning of these standards. Local systems should use standardized testing and evaluation measures that are aligned with state grade-level objectives in order to identify students who are having difficulty meeting grade-appropriate expectations for mathematics. These students might then receive additional and more focused instruction so that they can eventually meet both grade-level and state expectations. Teachers, school administrators, and parents all share a responsibility for identifying students needing intervention, but state coordination and dissemination of identification practices will make the development of identification systems more efficient.

Early intervention can prevent growing gaps in achievement and is a more promising approach for addressing underachievement than either grade retention or social promotion (Heubert & Hauser, 1999). Intervention programs should be targeted at struggling students before they fall behind and could take a variety of forms (e.g., tutoring, Saturday schools, after-school programs, after-school help rooms, summer programs). All intervention plans must include publicly disseminated expectations so that teachers, administrators, parents, and students understand when extra help is warranted and in what way the intervention is targeted to meet a student's needs. The responsibility for providing the intervention must be shared among the state, local school systems, and individual schools. Isolated classroom teachers cannot assume this responsibility alone. Due to the expense involved, the State must share funding resources for intervention programs with local school systems. State dissemination of model intervention programs will make the design and revision of intervention programs more efficient.

The Commission cautions against using the CTBS/5 for the identification of students needing instructional intervention. The CTBS/5 is not designed to chart students' progress towards meeting Maryland's mathematics standards and outcomes. Further, the CTBS/5 does not provide information that can be used by teachers to design mathematics instruction. Unlike the MSPAP, the CTBS/5 consists completely of multiple-choice items and does not reflect the mathematics process objectives within the *Maryland Mathematics Content Standards*. The mathematics content of the CTBS/5 for grades 2, 4, and 6 represents only a limited portion of the mathematics content presumed in the *Maryland Mathematics Content Standards*. Indeed, if a teacher in grades 2, 4, or 6 were to focus instruction only on those skills that are measured on the CTBS/5, his or her students' overall achievement that year would be limited. Further, although it may not be discernible on the CTBS/5 that year, students' base for learning mathematics in the future would be diminished.



Moreover, while the CTBS/5 provides individual student scores that allow parents to compare the achievement of their child to that of students across the nation, this does not provide an indication of how well a school is educating their child. In particular, a large part of a student's score on a norm-referenced assessment is "attributable to family background and opportunities before school and outside the classroom" (Barton, 1999, p. 21). Given the substantial fiscal demands associated with administration of the CTBS/5 and its limitations in evaluating and supporting student achievement, the current mandatory administration of the CTBS/5 in grades 2, 4, and 6 should be periodically re-examined.

Through its development of the Maryland Learning Outcomes and the Core Learning Goals, the State of Maryland has indicated that strong student achievement for both regular and special education students is a high priority. This recommendation aims to make it a reality. However, cooperative development of intervention programs and local assessments will require substantial funding at state and local levels. Together these efforts offer clear potential for greatly improving student achievement.

Responsibility: *Local school systems, the Maryland State Department of Education, the Maryland State Legislature, and Maryland Colleges and Universities*

4 **Eliminate use of the Maryland Functional Mathematics Test (MFMT) as a high school graduation requirement and support implementation of the High School Assessments (HSA).**

Rationale: The MFMT assesses sixth-grade mathematics skills, not the High School Core Learning Goals. State assessments should always be aligned with expectations as identified in State goals and content standards. Administration and scoring of the MFMT uses state funding for an irrelevant purpose. Further, the current use of the MFMT as a high school graduation requirement may be relegating mathematics curriculum, instruction, and assessment for special education students to the realm of basic skills in mathematics.

Responsibility: *Maryland State Department of Education*

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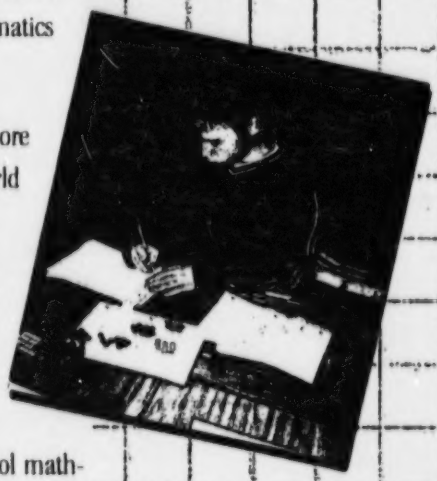
Background

CONCERNS ABOUT NATIONAL economic competitiveness have raised a number of critical questions about the content, organization, and pace of K-12 mathematics curricula:



- How can schools provide more substantial mathematics education for more students in order to equip them for careers in an increasingly technical world of work?
- How do the impressive new calculator and computer tools redefine mathematical concepts and skills?
- What mathematical topics are appropriate for school curricula?
- Is it feasible and/or advisable to accelerate the traditional pace of school mathematics curricula to give students earlier access to subjects like algebra in middle grades or calculus and statistics in high school?
- What is the interplay between mathematical concepts, procedural skills, and problem-solving strategies, and how should those facets of the subject be developed in school curricula?

As mathematics teachers and curriculum leaders in Maryland consider these issues, they can draw on insights from a variety of major policy statements by national professional groups (American Association for Advancement of Science, 1993; Learning First Alliance, 1998; NCTM, 2000; USDE, 2000a), from recent research on teaching and learning of mathematics at various levels (Bransford et al.,1999; Hiebert, 1999; Stigler & Hiebert, 1999, National Research Council, 2001a), and from major curriculum development projects that have explored new conceptions of K-12 mathematics education (USDE's Mathematics and Science Expert Panel, 1999).

Current Status

THE *Maryland Mathematics Content Standards* establish a framework of goals for school curricula that are aligned with recommendations from leading national professional organizations. They identify specific objectives in six content and four process areas. Content standards are developed in depth and breadth across the grade levels. Process

standards include the ability to reason, communicate, solve problems, and make connections among topics.

The *Maryland Mathematics Content Standards* describe expectations of core mathematical knowledge to be obtained by all students. It must be noted that such expectations seem at odds with the (common) practice of tracking for mathematics instruction. Many school mathematics programs have different content and learning expectations for students who have different aptitudes or interests. Many parents are eager to have their children accelerated through a curriculum that is both narrower in scope and more demanding than the content standards for all students. The most common goal for such an "honors track" is preparation for calculus, the first course in collegiate mathematics for students heading toward scientific or technical careers. The academic prestige of this path has created some unfortunate tensions in elementary, middle, and high school curricula. In particular, since algebra is an essential part of the foundation for calculus, schools are pressed to place more and more students in algebra courses at earlier points in the curriculum. This action has the unfortunate effect of condensing the content of the algebra course and short-changing important mathematical topics in geometry, measurement, probability, and statistics.

National standards, Maryland's state-mandated tests, and state curriculum standards influence curricula and curriculum development in local schools and districts. The Commission was unable to examine the intended or taught curricula in local school districts, so we have limited knowledge of the extent to which goals outlined in the *Content Standards* are in effect across the state. However, we have the general impression that local districts are working hard to align their curricula with the state framework and assessments. If this is accomplished, Maryland schools will have mathematics curricula that reflect national standards.

Vision

SCHOOL MATHEMATICS IN MARYLAND must provide students with a focused and comprehensive K-12 curriculum so that they have a sound foundation for future studies, successful careers, and effective citizenship. Such a curriculum will develop student knowledge of important concepts and skills in number, geometry, algebra, data analysis and statistics, probability, and measurement. It will also develop students' ability to reason, solve problems, and communicate mathematically. These curricular experiences should be pro-

It is not acceptable to present a strong mathematics program to a select group of students, while relegating others to programs of lesser quality.

vided in a way that assures acquisition of core competencies by all students and encourages full development of each student's potential. All Maryland students and their teachers should have access to research- and standards-based curriculum materials and teaching/learning resources.

Because mathematics is a dynamic and growing subject, curricula will need to adapt to new topics and technologies that become important tools in reasoning, problem-solving, and decision-making. Since the primary State influence on local school practice is through the variety of mandated statewide testing programs, it is critical that those tests be appropriately aligned with the best thinking on desirable curriculum goals and objectives.

Recommendations

IN SEVERAL RESPECTS, the *Maryland Mathematics Content Standards* are at the forefront of school curriculum reform. We recommend that the State continue to provide support for implementing the content standards. However, there are several issues on which the State can provide further leadership.

5 Ensure that all Maryland students have access to a challenging and inviting mathematics program.

Rationale: Research consistently shows that tracking students into different programs using mathematics test scores or prior grades unfairly disadvantages many students (Oakes, 1990, 1995). It is not acceptable to present a strong mathematics program to a select group of students, while relegating others to programs of lesser quality. Minority, poor, and special-education students are often inappropriately placed in mathematics programs that emphasize less challenging content, placing limits on the mathematics they can learn and their future educational and career opportunities.

Responsibility: *Local school systems and the Maryland State Department of Education*

6 Offer guidance about ways for local school systems to focus instruction on key topics at each grade level as they implement the *Maryland Mathematics Content Standards*.

Rationale: Typical United States mathematics curricula have been characterized as "a mile wide and an inch deep" because they often revisit many different topics year after year, never seeming to expect the mastery upon which future teaching and learning could be

based (Beaton, et al., 1996; Mullis, et al., 1997; Stigler & Hiebert, 1999). This tradition stands in striking contrast to most countries that have highly successful school mathematics systems. While we do not recommend inflexible detailed mastery expectations for all students at specific grade levels, we do believe that it would be desirable to identify topics that should be the focus of instruction at each grade level (e.g., developing number sense with whole numbers in early elementary grades, rational numbers in upper elementary grades, and proportional reasoning in middle grades).

Responsibility: *Maryland State Department of Education*

7 **Align state and local school system assessment programs with the content goals recommended by the *Maryland Mathematics Content Standards*.**

Rationale: When students, teachers, and schools are held accountable for attaining the goals expressed in mathematics content standards, classroom activities will reflect attention to those goals. The most influential State instruments for expressing curricular goals are the tests used to assess achievement of students, teachers, and schools. Assessment instruments that do not reflect the primary goals of the curriculum will undermine the state standards; assessments that are aligned with curriculum standards add important support to those recommendations. Recent experiences with the Maryland School Performance Assessment Program illustrate the positive influence of assessments that are aligned well with curriculum and instructional goals. A significant step toward such alignment will be accomplished when the High School Assessments (HSA) replace the Maryland Functional Mathematics Test (MFMT) as the graduation standard in mathematics.

Responsibility: *Maryland State Department of Education and local school systems*

8 **Ensure that all State initiatives involving early childhood education (pre-kindergarten and kindergarten) include attention to providing appropriate mathematical experiences.**

Rationale: Despite the many studies that demonstrate the complexity of young children's thought processes (Greenes, 1999), few preschool mathematics programs exist. Those that

do often have a limited vision of what young students should be doing. These programs frequently include nothing more than recognizing specific shapes and counting to ten. To facilitate young children's mathematical development, the preschool mathematics curriculum should change from a collection of unrelated activities to a cohesive program that introduces the important ideas of number, space and locations, shape, patterns, and measurement (NCTM, 2000). Good experiences that build on young children's informal knowledge are essential preparation for later study in a more formal school context.

Responsibility: *Maryland State Department of Education, local school systems, and community-maintained early childhood education programs*

9 **Ensure that algebraic concepts and skills are developed throughout the K-12 mathematics curriculum.**

Rationale: The ideas and techniques of algebra are essential tools in quantitative reasoning and problem solving throughout mathematics and its applications. The traditional United States curriculum for college-intending students includes two full years of algebra in high school. For many years highly able students have begun algebraic study in grade 8, and there is increasing pressure to extend that challenge and opportunity to more students. Such proposals are often justified with the argument that other countries introduce algebra as early as grade 6 or 7. However, those countries do not devote an entire year to the kind of formal algebra taught in United States courses. They continue parallel and interrelated development of topics in proportional reasoning, measurement, geometry, and data analysis — important topics that are weaknesses of United States students in the middle grades. We endorse focused development of algebraic concepts and skills at the middle-grade level. Such work should prepare students for the more formal study and assessment of algebraic knowledge in high school. The NCTM (2000) recommends substantial development of algebraic ideas in K-8 mathematics, but rejects simple translation of the high school curriculum one year earlier.

Responsibility: *Local school systems and the Maryland State Department of Education*

10 **Review the *Maryland Mathematics Content Standards* periodically to guarantee that they reflect the priorities and opportunities made possible by developments in calculator and computer technology.**

Rationale: As mathematical content topics and their importance shift it will be critical for the Maryland State Department of Education to assess continually the importance and role of the content standards in mathematics. Similarly, calculators and computers have become standard working tools in mathematics and powerful learning tools in school. In only three decades this technology has blossomed from the first hand-held calculators to hand-held computers with access to the Internet and software performing numeric, symbolic, and graphic calculations that could only be imagined before their introduction. The development of increasingly powerful hardware and software will only expand in the years ahead. Maryland mathematics students must learn how to use this technology effectively.

Responsibility: *Maryland State Department of Education*

11 **Require that all students study mathematics each year of high school. Encourage local school districts to develop high quality high school courses that provide appropriate and attractive options for students with different mathematical goals, interests, and aptitudes.**

Rationale: Mathematics is the essential language for expressing and analyzing quantitative and visual information in science, engineering, technology, business, government, and personal decisions. Whereas it was once possible for only a modest core of professionals to be mathematically literate, increasing levels of mathematical competence are now required for any citizen who wants to participate fully and successfully in the modern world. However, for many students the right mathematics in high school is not the narrow pre-calculus curriculum that is traditional fare in United States schools. A strong four-year high school curriculum should include significant content in data analysis, statistics, probability, and discrete mathematics, and it should allow students optional paths that prepare them for the diverse array of post-secondary school study and careers.

Responsibility: *Local school systems and the Maryland State Department of Education*

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Background

TEACHING AND LEARNING MATHEMATICS are complex activities. There are no magic plans, models or programs for helping all students learn or for ensuring that all teachers are effective. However, there are some things we do know about the instructional process. To be effective, teachers must know and deeply understand the mathematics they are teaching and be able to draw on that knowledge (NCTAF, 1996). Instruction also requires reflection on the parts of both teacher and learner. Students learn from experiences which teachers provide. These experiences are guided by the content and pedagogical background of the teacher. The task of presenting a challenging yet inviting classroom environment is a constant challenge for the best teachers. Moreover, students learn by connecting new ideas with their prior knowledge. An important assumption is that teachers know how to determine what their students already know and can then build on this knowledge. The ability to assess what students know, build on it, and provide appropriate learning activities on a daily basis is critical for instructional success.

As we know, learning mathematics is much more than acquiring a series of skills or memorizing basic facts or symbols. Learning mathematics is a process. The *Maryland Mathematics Content Standards* address the curriculum but do not provide actual recommendations for the delivery of instruction. Effective teaching requires knowledge and understanding of mathematics, of students as learners, and of pedagogical strategies (NCTM, 2000). The elements of effective instruction suggested above require long term support and adequate resources. Such opportunities must be ongoing and focus on the growth of the teacher as both a learner and one who delivers instruction to others, as will be discussed further in the Teacher Quality section.

Current Status

THE RELEASE OF THE CURRICULUM and Evaluation Standards (NCTM, 1989) and the creation of the Maryland State Performance Assessment Program (MSPAP) has influenced mathematics instruction in Maryland. Instruction has become more authentic and performance based. That is, problems and tasks are used to motivate lessons. The problems selected are often tasks with sub problems and may link to more than one content area of mathematics. (See Figure 1.)

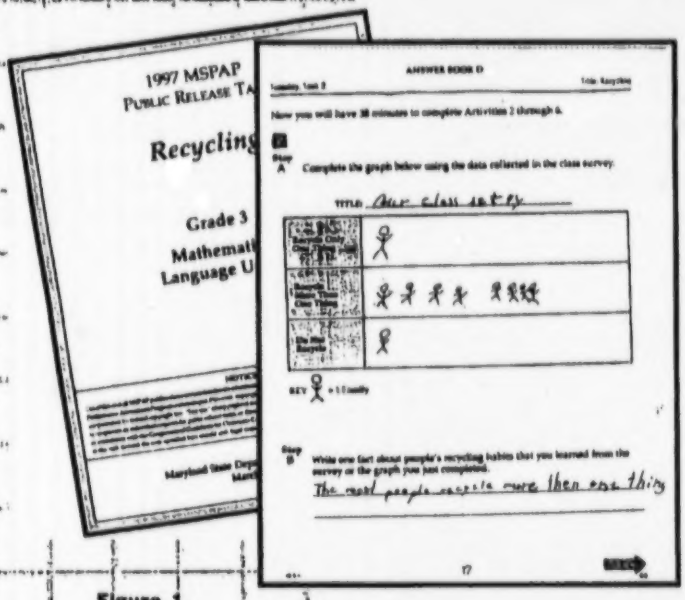
1997 MSPAP
Public Release Ta
Recycling
Grade 3
Mathemati
Language U
ANSWER BOOK D
Now you will have 30 minutes to complete Activities 2 through 4.
Step A
Complete the graph below using the data collected in the class survey.
Step B
Write one fact about people's recycling habits that you learned from the survey or the graph you just completed.
The most people recycle more then one thing
17

Figure 1. Sample Maryland State Performance Assessment Program (MSPAP) task.

However, review of the literature and discussion with professionals in the field indicate that the actual delivery of instruction varies. Each Maryland school system has the responsibility to determine its own regulations relative to the delivery of instruction, with the shared goal of meeting the State's content standards. Appropriate intervention strategies to ensure the success of all students also vary from school to school system. Additionally, each Maryland school system determines the amount of time mathematics is taught at each grade level and the best use of instructional time, including the use of block scheduling at the middle and high school levels.

Our work also indicates that professional development provided in mathematics, particularly at the K-5 level, is at best spotty throughout the state's school systems. Attention to mathematics pales in comparison to the the tremendous amount of attention given to reading, through efforts such as the "Reading by 9" campaign, and to the professional development provided for those who teach it.

Vision

EFFECTIVE INSTRUCTION must be grounded in the belief that all students can learn mathematics and that they will be supported in their efforts. Effective instruction includes, but is not limited to, the selection and use of appropriate curriculum materials, and grouping and questioning strategies. Well chosen problem-based lessons or mathematical tasks can arise from the "real-world experiences of students, or they may arise in contexts that are purely mathematical" (NCTM, 2000, p.19). But interesting problems or tasks are just the tip of the iceberg in the teacher's quest to provide quality instruction. It is the teacher who must determine the aspects of a problem on which to focus, the questions to ask and discuss, the level and time allotted for discussing a problem, and how to support students while still challenging them. Instruction must be orchestrated. It is our hope that every student in Maryland will learn to understand and use mathematics as a result of carefully designed experiences consisting of active engagement with rigorous mathematical content. The teacher needed to implement such lessons on a regular basis must have strong background knowledge in mathematical content and pedagogy, be able to use technology, and be highly skilled in assessing students on both a formative and summative level. It is also

our hope that Maryland teachers will have more opportunity to collaborate with colleagues regularly in efforts to analyze, discuss, deepen, and improve their content and pedagogical knowledge, the importance of which is discussed further in the Teacher Quality section.

Recommendations

TO ADDRESS ISSUES related to improving the quality of mathematics instruction, the Maryland Mathematics Commission recommends the following:

12 Support teachers' efforts in meeting the expectation that they will provide instruction that facilitates mathematical proficiency—factual knowledge, procedural fluency, and conceptual understanding.

Rationale: Teachers need ongoing support in helping children learn mathematics. The link between factual knowledge (e.g. basic number combinations), procedural fluency, and conceptual understanding is an important one (Bransford, Brown, and Cocking, 1999). In essence, what students learn is connected to how they learn it. Facts and procedures need to not only be acquired, but understood. Learning with understanding makes subsequent learning easier. Poorly organized and repetitious mathematics instruction frequently results in teachers repeating the same material year after year. Simply asking students to explain something isn't sufficient. Students need to understand mathematics at a level that will allow them to explain their thinking. By having students explain their thinking teachers help them build on their informal knowledge. In such settings procedural fluency and conceptual understanding of important mathematical ideas can be developed (Lampert, 1989). Managing this critical link between factual knowledge, procedural fluency, and conceptual understanding is a challenge for most teachers. They need to be supported in their efforts to provide such balance in their instruction.

Responsibility: *Local school systems*

13 Provide teachers with opportunities to develop a repertoire of teaching strategies which will provide students with opportunities to become competent problem solvers and critical thinkers, and enable them to construct meaning for important mathematical ideas.

Rationale: Kepner (2000) likens learning mathematics to an intellectual contact sport. As students learn they should try new ways, defend their solutions, and discuss reasoning with

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others. Such learning is best done in an environment where teachers can help students "learn to make conjectures, experiment with various approaches to solving problems, construct mathematical arguments, and respond to others' arguments," (NCTM, 2000, p.18). The most effective teaching takes place when students are engaged in meaningful mathematical tasks, tasks that are used to teach important concepts and provide intellectual challenges for students.

Responsibility: *Local school systems*

14 **Support the expectation that teachers will continuously use varied strategies in order to monitor, enhance, and assess student learning.**

Rationale: Retention is improved by daily, cumulative review (Leinwand, 2000). Integrating review and assessment into the regular routines of the classroom can help teachers identify and communicate instructional goals: "By providing information about students' individual and collective progress toward the goals, assessment can help ensure that everyone moves productively in the right direction" (NCTM, 2000, p. 23). Teachers should be encouraged to use a variety of assessment strategies. Such assessments guide instructional decision making.

Responsibility: *Local school systems*

15 **Ensure that all elementary and secondary students receive one hour of mathematics instruction per day. Students in half-day and prekindergarten programs must receive a minimum of 90 hours of mathematics instruction per year.**

Rationale: Assuming the typical school day is about six hours in length, it is not excessive to dedicate one sixth or about 16% of that time to mathematics teaching and learning. This is especially true, considering the importance of the subject, and the needs of employers relative to quantitative skills and a background in problem solving and reasoning. Less than an hour of instruction per day deprives students of the opportunity to develop skills and understandings and compete in an increasingly problem-based, technologically driven society and culture. According to Leinwand (2000), "Students whose formal mathematics period is 60 minutes per day receive nearly 180 hours of instruction a year, fully 50% more time than students in 40-minute periods."

Responsibility: *Local school systems*

Background

TODAY, RESEARCH IS CONFIRMING what common sense has suggested for quite some time: A skilled and knowledgeable teacher can make an enormous difference in how well students learn (Public Agenda, 2000). More significantly still, these studies indicate that teacher quality is the single best predictor of student success (MSDE, 1999b, p. 35). Linda Darling-Hammond of Stanford University found that the strongest predictor of how well a state's students performed on national assessments correlated with the percentage of teachers who were fully certified and had majored in the content areas they taught (Public Agenda, 2000). Yet another study indicated that low-achieving students assigned to effective teachers gained approximately 53 percentile points on standardized tests during a school year, while those assigned to the least effective teachers gained only 14 percentile points (Sanders & Rivers, 1996).

Knowledge of how to teach is as important as knowledge of what to teach. Good teachers know how to guide and encourage student learning, how to plan productive lessons and diagnose students' problems, as well as knowing the content to be taught (Darling-Hammond, 1994). Effective teachers have the ability to organize the mathematics so that fundamental ideas form an integrated whole. Teachers also need to be able to adjust and take advantage of opportunities to move lessons in unanticipated directions (NCTM, 2000). In addition, teachers must continually develop, maintain, and effectively implement technological skills in order to enhance and facilitate student learning, the benefits of which will be discussed in the Technology section. Thus, mathematics teaching quality depends upon adequate professional training and certification, as well as ongoing professional development.

Current Status

ACCORDING TO THE Maryland State Department of Education, every student should have teachers who are trained thoroughly in both content and pedagogy, and who have proper credentials in the courses they are teaching (MSDE, 1999b). These teachers are to participate in professional development activities that continually expand their knowledge and hone their skills. Teachers having these attributes should be available to every student regardless of reform agenda or school improvement mandate.

Nationwide, only 17 states offer middle school certification in mathematics (Public Agenda, 2000). The remaining states, including Maryland, staff middle schools with either secondary (7-12) or elementary (1-6) prepared teachers. At present, 33 states allow middle school educators to teach with generic certificates spanning the elementary and middle years.

Only nine states require all prospective middle school teachers to pass tests in their academic disciplines (Public Agenda, 2000). At this writing, all middle schools in Maryland offer algebra as an eighth grade mathematics course for those students selected for such advanced study. Some school systems offer algebra to all eighth graders. Some offer algebra to specially selected students at Grade 7 with these students then moving to geometry by Grade 8. This move toward algebra-for-many or algebra-for-all at the middle school level has presented both curriculum and staffing challenges as more teachers without the proper training are assuming these responsibilities. School districts have had to use provisionally certified teachers, elementary certified teachers, and teachers from other fields (e.g. physical education) to fill teaching "slots" at the middle school level.

Students preparing to teach in Maryland and who are completing MSDE-approved NCATE approved teacher certification programs are required to develop the mathematics content background and skills that are suggested by MSDE-recognized professional organizations in the field. These organizations include:

- National Association for the Education of Young Children (NAEYC), Early Childhood Education
- Association for Childhood Education International (ACEI), Elementary Education
- National Council of Teachers of Mathematics (NCTM), Mathematics Education, K-12
- Council for Exceptional Children (CEC), Special Education

In contrast to these general guidelines, the Conference Board for Mathematical Sciences (CBMS), a consortium of 16 mathematics organizations, has recently completed a report on the content background of mathematics teachers, offering very specific recommendations for the actual mathematics content that Maryland teacher candidates should know and understand (CBMS, 2001). This report recommends content requirements for prospective elementary, middle, and high school teachers. In addition, the CBMS report calls for mathematics specialists at fourth grade and above. This supports the NCTM's recommendation that the use of mathematics specialists at the elementary school level is an option well worth pursuing (NCTM, 2000).

Vision

IT IS OUR HOPE that all students, each year of their PreK-12 education, will be instructed by fully certified mathematics teachers. Such teachers will have the content knowledge, pedagogical skill, and the love of mathematics required to challenge and support all stu-

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dents. Certification for elementary mathematics specialists will allow schools and school systems to provide more opportunities for students at a younger age and to assist those students needing intervention. Opportunities should be provided by the Maryland State Department of Education to support middle school certification. Schools and school systems should continue to provide new teachers with opportunities that foster growth.

Recommendations

To address issues related to improving teacher quality, the Maryland Mathematics Commission recommends the following:

16 **Require pre-service early childhood, elementary and special education teachers to successfully complete mathematics and mathematics education coursework that reflects the content areas and topics suggested by the *Mathematical Education of Teachers* (CBMS, 2001).**

Rationale: While Maryland State Department of Education approved programs in teacher education require that all prospective teachers should possess substantive backgrounds in mathematics content and related pedagogy, actual requirements have not been articulated. This issue seems to be especially critical given the limited mathematics and mathematics education requirements of early childhood and special education students at the pre-service level. Specialty courses such as those entitled "Mathematics for Elementary Teachers" are currently used throughout Maryland to satisfy the mathematics content background requirements of early childhood and/or elementary teachers. These courses attempt to address *all* content areas in the PreK-8 mathematics curriculum in one course or in some cases, a two-course sequence. Such a "shotgun" approach to this area of need is counter to the mission and goals of the Commission. Future program approval visits and NCATE evaluations of teacher education programs at Maryland institutions of higher education should verify that the mathematics required of prospective early childhood, elementary, and special education teachers corresponds to the recent Conference Board of Mathematical Sciences recommendations (CBMS, 2001).[1] It should be noted that similar content background guidelines are suggested in the CBMS report for middle school and high school teachers of mathematics.

[1] These include the following expectations at the PreK-8 level:

Number and Operations

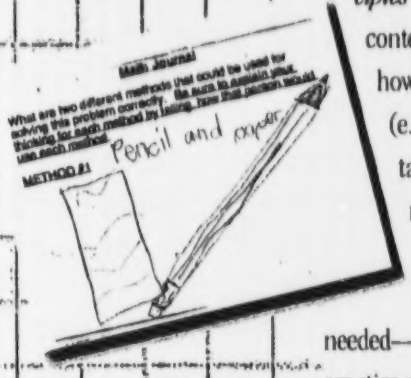
- Understanding operations on whole numbers (i.e., the set of natural numbers and zero) including having a large repertoire of interpretations of addition, subtraction, multiplication and division and of ways they can be applied
- Understanding multi-digit calculations, including standard algorithms, "mental math" and non-standard methods commonly created by students

These should also provide guidance to MSDE as they approve and monitor teacher education programs within the state.

Responsibility: *Maryland State Department of Education*

17 **Establish an elementary mathematics specialist certificate.**

Rationale: Mathematics is important at every level of schooling. We need to recognize that because of the increasing mathematical sophistication of the curriculum, particularly in grades 3-5, the development of teacher expertise is essential (NCTM, 2000). *The Principles and Standards for School Mathematics* (NCTM, 2000) notes how mathematical content develops on trajectories related to learner development. Teachers need to know how the roots of mathematically sophisticated content areas develop in the early grades (e.g. algebra, reasoning and proof, etc.), and are extended through the upper elementary years and on into middle school. They need a deep, rich understanding of the mathematics content and pedagogy at the elementary level. Such a background is not typical for most elementary classroom teachers. Additionally, if Maryland is sincerely interested in assisting all children in learning mathematics, support is needed—support for children and support for other teachers. Elementary school mathematics specialists may teach across or within grade levels at the building level (e.g., be responsible for all fourth grade mathematics). They could be responsible for mentoring teachers in mathematics at the building level and beyond. Specialists could help direct the mathematics component of school-wide intervention programs. They should also be valued


Math Journal
What are two different methods that could be used for solving this problem correctly. Be sure to explain what thinking for each method by listing how that person would use each method
Pencil and paper
METHOD #1

- Developing a strong sense of place value
- Extending the domain beyond whole numbers to integers and rational numbers.

Geometry and Measurement
- Developing spatial sense, including an understanding of one, two, and three dimensions
- Understanding basic shapes and their properties
- Communicating geometric ideas
- Understanding length, area, and volume.

Algebra
- Representing arithmetic generalizations symbolically
- Recognizing computation algorithms as applications of the field axioms
- Understanding the idea of function and variable.

Data Analysis, Statistics, and Probability
- Designing data investigations
- Describing data
- Drawing conclusions
- Developing initial ideas of probability.

allies in planning and implementing professional development programs in elementary school mathematics. In short, such specialists represent a critical cadre of elementary classroom teachers with mathematics education expertise.

The proposed elementary mathematics specialist certification program should be at the graduate level and include a prerequisite of three years of successful classroom teaching at the elementary level and coursework that reinforces, builds upon, and extends learning from the pre-service level. This would include enough study of advanced mathematics so that specialists can see the next few years for their students — mathematics wise.[2] This certificate is in many ways analogous to the reading specialist certificate already in existence in Maryland and most other states.

Responsibility: *Maryland State Department of Education*

18 Establish a teaching certificate in middle school mathematics.

Rationale: According to information provided to MSDE by Maryland mathematics supervisors, in the majority of Maryland school districts, less than half of the middle school mathematics teachers are certified as secondary mathematics teachers. This sobering fact is of great concern at a time when more and more middle school students are being exposed to important and sophisticated concepts in algebra, geometry, and proportional reasoning. It is critical that those teachers charged with the conceptual beginnings of higher level mathematics know and deeply understand the mathematics they are charged to teach. Mathematics courses necessary for middle school mathematics certification must provide teachers with an in-depth understanding of the mathematics they will teach, which should also provide a view of where that mathematics is headed for their students (Ma, 1999). Coursework in mathematics education must develop instructional strategies that optimize the mathematics achievement of diverse learners. This recommendation also supports the request of Maryland mathematics supervisors for the establishment of middle school certification. In addition, the MSDE's Middle Learning Years Task Force recommends that middle school teachers should participate in a program of study that, "provides appropriate content for a

[2] For example,

Mathematics Courses - 12 credits, with a focus on:
- Number and Operations
- Geometry and Measurement
- Algebra
- Data Analysis, Statistics and Probability

Mathematics Education Courses
- Issues in Teaching and Learning Mathematics
- Diagnosis and Assessment and Mathematics
- Educational Research
- Technology, Telecommunications, the Internet and Mathematics

major in the field and professional education experiences appropriate to the understanding of early adolescent development" (MSDE, 1999c, p. 30). This recommendation also reflects national concerns expressed by Felner (1995), Ferrini-Mundy & Johnson (1994), Phillips & Lappan (1998), Silver (1998), and others.

The proposed middle school mathematics certificate should require elementary teachers to earn a minimum of 21 credits in mathematics and to take a mathematics methods course focused on the teaching and learning of middle school mathematics. The mathematics courses to be reviewed for middle school certification (typically grades 6-8) should include specific courses in algebra, geometry, statistics and probability, and number and operations. Those candidates seeking middle school mathematics certification via MSDE "credit count" review should have a minimum of 21 credits in mathematics with specific course work in algebra, geometry, statistics and probability, and number and operations. A course specifically focusing on the teaching and learning of middle school mathematics should also be required. All middle school mathematics should be taught by a teacher certified in middle school or secondary mathematics. All high school mathematics should be taught by a certified secondary mathematics teacher.

Responsibility: *Maryland State Department of Education*

19 **Provide all teachers of mathematics with regularly scheduled, meaningful professional development opportunities in mathematics and mathematics education.**

Rationale: If teachers are to provide the active learning experiences required for highly effective mathematics instruction, their own professional development must be ongoing and supported. Professional development programs and opportunities must carefully examine the expectations in new curriculum frameworks and assessments and understand what they imply for teaching and for learning to teach (NCTAF, 1997). Teachers' work and time needs to be reconfigured to allow for regular episodes of professional development at the classroom, building, school, and district levels. Moreover, teachers should be afforded opportunities to collaborate with colleagues as part of their professional development in order to pool knowledge, evaluate teaching methods, and compare results (Stigler & Hiebert, 1999). Professional development opportunities and their delivery should emerge as a partnership which reflects needs at the building level and expertise drawn from the school district, Maryland State Department of Education and college/university levels.

Responsibility: *Local school systems, the Maryland State Department of Education, and Maryland Colleges and Universities*

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Background

RECENT STUDIES have found a strong link between technology, academic achievement, and classroom instructional practices. Eighth graders whose teachers used computers mostly for mathematics "simulations and applications"—activities generally associated with higher order thinking—performed better on the 1996 National Assessment of Educational Practices than students whose teachers did not (Wenglinsky, 1998). In addition, a statistically significant difference was found between student performance on standardized tests and the manner in which teachers were implementing technology in the classroom when using the Metropolitan Achievement Test (Middleton, 1998).

Technology not only influences how mathematics is taught and learned, but also what is taught when a topic appears in the curriculum. With appropriate technology at hand, students can explore and solve problems involving large numbers. They can investigate characteristics of shapes using dynamic geometry software and discover societal trends using spreadsheets and other appropriate software. Students in North Carolina created virtual environments in a technical mathematics class and were then able to find the dimensions and calculate the costs of painting the rooms and putting carpet on the floors using "real" newspaper ads to find the cost of paint and floor coverings (Basal, 1995). Students in Australia used Desktop virtual reality to build geometric solids. By studying the solids inside as well as outside, shrinking and expanding objects, and deforming and joining them, they gained a greater understanding of geometric concepts than would have been available by working with conventional wooden models (Ainge, 1995). With the support of newer technologies, these complex problem-solving skills become accessible to both learning disabled and non-disabled students ("NCSU Computer Engineer," 1995).

An important tool of the technology-based classroom is the graphing calculator. Some worry that the graphing calculator "does the work" for mathematics students. In fact, once students have mastered basic computational skills by hand, the calculator can enable them to focus on problem solving and higher-order thinking skills by reducing the time spent on "big number" computations. Lessons prepared with the graphing calculator can help students explore and develop number sense (including mental computation and estimation) and encourage creativity through experimentation in problem solving. The graphing calculator also allows students to organize and store data and to create graphs based on the data or other functions. This gives students visual representation of the concepts being covered and helps them see the connections between mathematics and science. Efficient production has made calculators affordable, and their compact size makes them readily available for classroom activities and homework.

The Internet is one of the most powerful tools of technology in today's classroom. The *Maryland Technology Plan* (MSDE, 1999e) describes how classroom Internet connection can help students achieve academically. The plan proposes that students are better able to master skills and knowledge by accessing appropriate Internet sites. Internet access provides classroom variety and a break from normal classroom activities. It gives students a valuable research/reference tool and makes classroom material interesting. The Internet also enables students to collect real world, up-to-the-minute data, analyze the data, and then share findings and conclusions with others.

Distance education also has the capacity to address the needs of a diverse spectrum of learners. For students in remote locations, distance education can increase course selection and, on occasion, provide students with higher quality instruction because distance courses may be taught by content experts or excellent teachers (USDE, 1996). According to former Secretary of Education Riley (2000), only 49% of the nation's schools offer Advanced Placement (AP) courses and only 10% of the students take these demanding courses. The Maryland State Department of Education has begun a program to provide intervention assistance for students in mathematics (MSDE, 1999b). Distance education could be described as one of the appropriate interventions to enable students to meet state standards in mathematics. Important in all cases is the fact that studies suggest there is no significant difference in outcome (grades, test scores, retention, job performance) between courses being taught face-to-face and being taught at a distance (MSDE, 1999b). Access to technology, however, remains a critical issue (McLaughlin, 1999). Schools across the country are working to make technology accessible to all students (Zernike, 2000; La Pointe, 1999; Causey, 2000; Eggen, 2000). The importance of technology to the business community may also result in educational technology support from the private sector (Internet Firms, 1999; Blair, 2000; Trotter, 2000; Armour, 2000). Teachers, administrators, parents, business leaders, and students are looking to technology to enrich mathematics learning.

Current Status

ACCORDING TO the Maryland State Department of Education's most recent *Maryland Technology Inventory*:

- 81% of elementary and secondary teachers have the ability to use the computer independently for basic operations.
- 74% can use the Internet to browse the web and use e-mail independently.
- 60% are capable of integrating technology in the classroom.

(Reeves & Johnson, 2000)

Technology not only influences how mathematics is taught and learned, but also what is taught when a topic appears in the curriculum.

However, teachers can only work with the resources that are available to them. Last year, the 83,590 students enrolled in courses for the algebra/data analysis assessment shared 41,984 graphing calculators leaving a need for 41,606 graphing calculators (Crawford, 2000). While the Maryland State Department of Education was able to provide 1.5 million dollars through Goals 2000 funding to help with the purchase of graphing calculators, this did not completely fill the need. The recently (2000) failed House Bill 1120, proposed by Charles Barkley of Montgomery County, would have benefited all of Maryland's 23 counties and Baltimore City by providing the remaining funds necessary for graphing calculator access for all Maryland students completing high school algebra/data analysis assessment. This defeat has drawn attention to the technology equity issue throughout the state.

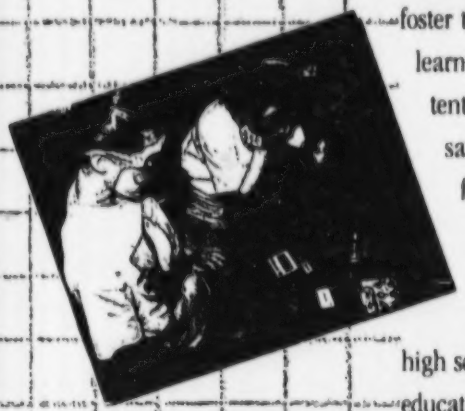
Electronic technologies such as portable word processors and brailers, electronic communication with speech capability, or computers with adaptive devices are needed in the assistive technology program used by teachers for students with disabilities or for students with learning difficulties. A recent Maryland survey reported that while 73% of the teachers surveyed indicated there was a need for this technological assistance, only 19% of Maryland teachers were aware of these options. Many of those who were aware of the options were not trained in using the technology, and only 15% of the teachers felt there was a clear process in place for obtaining assistive technology information (Reeves & Johnson, 2000).

In 1999, there were 46,795 mid- and high-capacity computers in Maryland classrooms and a student-to-computer ratio of 8:1, despite the state recommendation of 5:1 as the appropriate ratio (Reeves & Johnson, 2000). Ninety-nine percent of all elementary/secondary schools have Internet access in at least one location and 89% of Maryland schools have direct, full-time Internet connections. However, only 57% of Maryland classrooms have Internet access (Reeves & Johnson, 2000). More serious inequities exist within the Baltimore City Public School system where only 21% of the classrooms have internet access and no graphing calculators were purchased with FY99 Maryland Equipment Incentive Fund monies (Reeves & Johnson, 2000).

The National Council of Teachers of Mathematics advises that "technology should be used wisely and responsibly, with the goal of enriching students' learning of mathematics" (NCTM, 2000, p. 25). The presence of technical coordinators in the schools could help to fulfill this goal, yet the recent inventory indicated that only nine percent of the schools responding have a full-time coordinator and only six percent have a part-time coordinator. A full 32% of the schools responding reported a continued need for this position (Reeves & Johnson, 2000).

Vision

OUR VISION is to provide all students and teachers with the opportunity to use technology to support and extend student learning. Although technology should not be used as a replacement for basic understandings and intuitions, it can and should be used to foster those understandings and intuitions. Mathematics teachers find that students can learn more mathematics more deeply with the appropriate use of technology, and its potential as a tool for mathematics education when used appropriately is clear. The necessary technological tools must be made available to all schools, teachers, and students for class work and for homework, at school sites and via distance education. Leaders from academe, and business have long warned the country's economic leadership that an education system that is lagging behind in technological advances may be a drag on America's new economy More importantly, we must prepare Maryland's high school graduates to enter the workplace with the technology skills and mathematics education that will help them succeed.



Recommendations

TO ADDRESS ISSUES related to technology and mathematics teaching and learning, the Maryland Mathematics Commission recommends the following .

20 **Ensure that all mathematics students have appropriate access to calculators, computers and internet connections for class work and homework. Teachers shall incorporate the use of such technology into the delivery of mathematics instruction.**

Rationale: Calculator use in mathematics at all levels has been debated since the first four-function and scientific calculators appeared in the early 1970s. The calculator is an important instructional tool. However, we fully recognize that calculators do not replace fluency with basic number combinations, conceptual understanding, or the ability to use efficient and accurate methods for computing. Rather, the calculator should support these goals. Since 1985, when the first user-friendly calculators appeared that could graph functions, there has been movement to produce calculators that can now solve literal algebraic equations, manipulate algebraic expressions, differentiate and integrate, and solve systems of equations. Just as their earlier four-function counterparts raised questions about the amount of paper-and-pencil arithmetic a person needs to know, these symbol manipulators have

forced an examination of the amount of paper-and-pencil mathematics a person needs in algebra through calculus and beyond. Calculators do not hinder students' acquisition of conceptual knowledge; rather, such use significantly improves their attitude and self-concept concerning mathematics (Hembree & Dessart, 1992). Other studies have shown that calculators can have a positive effect on conceptual knowledge (Smith, 1997) and that they can facilitate the development of number sense resulting in better performance on items including place value, decimals, negative numbers, and mental computation (Groves & Stacey, 1998). Maryland ranked fourth in the country and had its highest SAT math scores in five years when 65% of Maryland's students who took the SAT (which allows calculator use) had an average mathematics score of 509 out of a possible 800 (Peiffer, 2000).

Web sites afford students the opportunity to obtain calculator use training while they are doing homework away from school. Students can learn to use a pocket calculator or graphing vector calculator as appropriate for their needs both in the classroom and at home via the Internet (Math, 2000). As noted, the calculator should function as a tool and is not intended to replace computational fluency. Once fluency is achieved, however, calculators not only facilitate the exploration of numbers and operations with numbers (number sense), they allow students who have trouble with computation or procedures to move forward in their mathematics study (Usiskin, 1999).

Computers are powerful problem-solving tools. The power to graph a relationship instantly and to systematically change one variable and observe what happens to other related variables helps students to become independent doers of mathematics (NCTM, 2000). Some literature optimistically indicates that all students will have modern multimedia computers connected to the information superhighway in their classroom in the near future (USDE, 1996). However, in several high poverty areas in Maryland student-to-computer ratios are well below average for the State (Crawford, 2000). Many schools have been unable to afford enough computers to create a technology-rich educational environment; however, monitoring the technology market and technological innovations may help us to remedy this inequity. For example, an Internet computer unveiled in May of 2000 costs only $376 and navigates the Internet just as well as machines costing hundreds more (Trotter, 2000).

The computational capacity of technology tools with Internet access extends the range of problems accessible to students and also enables students to execute routine procedures quickly and accurately, thus allowing them time for conceptualizing and modeling (NCTM, 1998b; Reeves & Johnson, 2000). The Internet makes extensive data sets available to everyone with access, providing opportunities for students to combine data collection analysis,

research and writing skills. Such opportunities can make a measurable difference in student performance. Students working with the Internet typically score about 20 points higher than the state and national averages on the mathematics portion of the SAT (Peiffer, 2000).

The adoption of mathematics software for computer use by students at the pre-school, elementary, middle school, and high school level has grown considerably. A recent technology review reported specific mathematics software as "best" or "most valuable" for students: The inductively-oriented program, Geometer's Sketchpad, was mentioned by more than 1/5 (21%) of all math teachers who reported a "most valuable" software title for use with their students. This was an unexpected finding since Geometer's Sketchpad is oriented toward inductive reasoning and the exploration of hypotheses (Becker, Ravitz & Wong, 1999). This example demonstrates the popularity in current mathematics software, a popularity that represents not just newer "bells and whistles," but shifts in approaches to instruction. Students who do not have access to newer, more valuable software will be at a disadvantage. We must carefully follow developments in educational software and provide teachers access to it. In conclusion, research and best practice provides ample evidence that when technology is used appropriately, students not only learn more mathematics, they engage with it more thoroughly (Dunham & Dick, 1994; Sheets, 1993; Boers van Osterum, 1990; Rojano, 1996, Groves, 1994).

Responsibility: *Local school systems*

21 **Require that candidates for initial and permanent certification as school administrators and (K-16) mathematics teachers demonstrate computer, calculator, and Internet skills and have the ability and willingness to incorporate technology/multimedia into mathematics instruction.**

Rationale: Mathematics teachers today are regularly bombarded with reasons why it is necessary to change the way mathematics is taught. The National Assessment of Educational Progress (NAEP) shows that students' knowledge and skills are very fragile and apparently are acquired without much depth or conceptual understanding (Heibert, 1999). Technology has the potential to help students move past basic skills to problem solving and higher order mathematics. However, if technological tools are to provide the most benefit to students, teachers must understand how to use them, as well as how to integrate them successfully into their classrooms and curricula. Specifically, mathematics teachers and school administrators at "all levels should promote the appropriate use of technology to enhance

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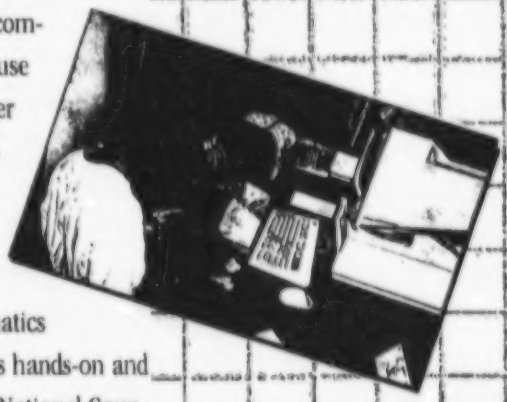
instruction by using technology in instructional settings, integrating technology use in assessment and evaluation, remaining current with state-of-the-art technology and considering new applications of technology" (NCTM, 1998b, p. 251).

When teachers are unfamiliar with computers and software, unexpected computer crashes and computer anxiety in general can increase the teachers' level of anxiety in a mathematics class (Weil, Rosen & Wugalter, 1990). Schools should seek computers and software that is substantive as well as easy for teachers to use (SureMath, 2000). It is important that teachers are trained in the computer functions and programs that will make them successful guides to using technology in the classroom. Such training might range from acquainting teachers with standard features of computer programs that allow for backtracking and correcting mistakes to teacher participation in such programs as Connected Classroom, which offers K-12 and higher education mathematics faculty and administrators a world- class Internet conference that promotes hands-on and minds-on projects such as GlobaLearn, Maya Quest, and Math Forum. The National Council of Teachers of Mathematics notes that,



> The use of calculators, computers, the Internet and other technology that support teacher innovation and the continual refinement of practice in the mathematics classroom must be supported at all levels. It is essential that mathematics teachers continue to learn about and explore the impact of calculators and computers and the perspective they provide on an expanding array of mathematical concepts, skills and applications.
>
> (NCTM, 1998b, p. 251)

New teachers should come to the classroom with an even higher degree of preparation. The Governor's Commission on Technology in Higher Education recommends that in order to be certified to teach in Maryland prospective teachers should be able to demonstrate basic computer skills and the ability to use a computer in multimedia instruction (MSDE, 1998b). Moreover, technology use is correlated with the ability of administrators to make informed decisions. Thus, technology requirements in teacher preparation and continuing certification programs will have an even greater impact in developing the skills of administrators who typically begin their careers as teachers (Trotter, 1997).

By using technology with Internet access students can visualize mathematical concepts and look for creative solutions to real world problems. Further, teachers may use this technology to help them meet the challenge of organizing mathematics instruction so that it attracts and develops the ability of the greatest number of students possible. Teachers are creative, knowledgeable professionals, who can quickly see the power of technology when it

is used to enhance student learning and who can use the Internet as a data source when they believe that students process best what is real to them. So much information available on the Internet—from weather data and air flight information to track and field world records—can be used to engage students in mathematics (Spicer, 2000). Curriculum development and instruction must take into consideration how technology will be used and how it may impact the curriculum—every day. (NCTM, 1998b).

Responsibility: *Maryland Colleges and Universities and the Maryland State Department of Education*

Background

"I'm not good in math."
"My Mom said she wasn't good in math when she was in school."
"When am I ever going to use this stuff?"
"I hate math."
"I never understood math and don't know how things work."

THE COMMENTS ABOVE or variations of such comments are too often heard by teachers of mathematics. Mathematics, it would seem, is right up there with snakes, public speaking, and heights in terms of common phobias (Burns, 1998). Yet, as indicated earlier in this report, employers in most fields have identified the need for employees who can reason and solve problems—that is, do mathematics.

Given the fear factor and the relative unpopularity of mathematics, clearly we have an image issue. We know that people who have quantitative skills and problem-solving abilities are generally destined for higher education, challenging and varied employment opportunities, and financial success. We also know that Maryland children are not doing as much or as well as they could and should in mathematics. The challenge is to harness younger students' enthusiasm for and interest in learning mathematics and extend and nurture it throughout all levels of schooling. To do this, we not only need to inform parents and the general public, but also to recruit them and others for the mathematical journey ahead. Mixed messages are often sent to educators and the public, sometimes indirectly. For instance, the ongoing "Reading by 9" initiative has been reinforced by the recent state decision to require a minimum of 12 credits in reading at the pre-service level of elementary teacher education. But, should early childhood and elementary teachers only know about reading? Will such a slant extend the mathematics fear factor expressed earlier by emphasizing one important learning area over another? What about mathematics? Perhaps we needs our own campaign—mathematics for a lifetime!

Early in the instructional lives of their children, parents need to know about the importance and value of mathematics. They also need to know about important goals in the mathematics curriculum of their children. Some have said that learning mathematics is simply finding the answer to a computational exercise. Mathematics learning should include appropriate attention to number and operations, algebra, geometry, measurement, and data analysis and probability taught via experiences that cause students to reason and communicate as they solve problems. Many students have learned to be somewhat successful in mathematics (i.e., pass mathematics courses) without understanding what they are

doing. Too many students and former students have not had the opportunity to be actively engaged in learning and doing mathematics, a legacy that has contributed to both parents' and students' negative perceptions.

Current Status

ALL STUDENTS in Maryland receive instruction in mathematics at the early childhood, elementary, middle school, and high school levels. In addition, opportunities exist for gifted and talented or enrichment programs in mathematics at the elementary and middle school levels. Some school systems use Title I funds to support remedial mathematics programs at these levels. Most Maryland middle schools offer a course in algebra at the eighth grade level for those students prepared to enter such a course. The prerequisites vary by school system. In several Maryland school systems, the more advanced students complete coursework in Algebra I at grade seven and Geometry at grade eight. High school mathematics options include Algebra II, Geometry, Analysis, Statistics, Calculus, Discrete mathematics and other courses. In addition, a growing number of Maryland students are now completing the Educational Testing Service's Advanced Placement (AP) tests in mathematics.

Unfortunately, many parents feel ill equipped to assist their children with homework assignments used to support and reinforce the mathematics their children are learning. The same parents who find time to read to their children do not have the time or inclination to review solutions to mathematics problems. We need to make a concerted effort to inform everyone that, for instance, there is no mathematics "gene," that neither mathematics teachers nor mathematics learners are nerds. The message needs to be sent that mathematics is important for all learners.

Vision

AT PRESENT there is no statewide group or procedure for publicizing the importance of mathematics for all students. Maryland needs a plan to carry out this important work. Schools and teachers need to provide experiences that will help students and their families recognize the value of mathematics beyond the classroom. This plan could provide for the development of materials to be used with parents, children, and teachers at the elementary and middle school levels. At the high school level the plan may consist of an organized group of resource people who visit classrooms to discuss how mathematics is important in their lives. Such efforts should be considered, perhaps by the Maryland Council of Teachers

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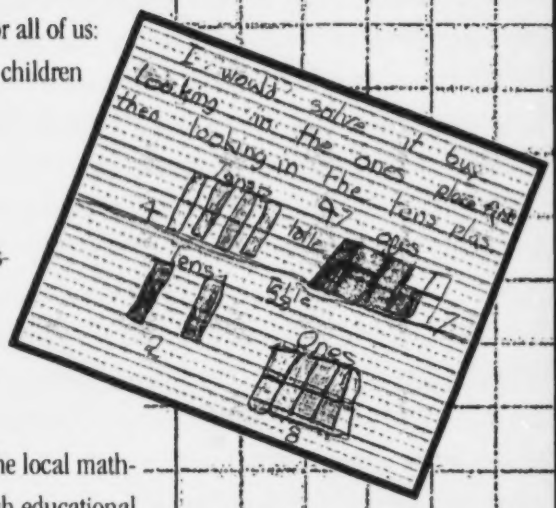
of Mathematics. Quality mathematics teaching and learning is important for all of us: "We need to change how we think about and relate to mathematics. Our children deserve nothing less" (Burns, 1998, p. 145).



Recommendations

TO ADDRESS ISSUES related to outreach, the Maryland Mathematics Commission recommends the following:

22 Collaborate with communities and businesses to support lifelong mathematics literacy.

Rationale: It is important that schools work with the community to raise the local mathematics profile. All institutions bear the responsibility for enforcing the high educational capabilities of its populace. Colleges and universities should participate in strategies that help to strengthen standards and competencies for their incoming students. Businesses can contribute by providing the much-needed incentive to students through mentoring programs where first-hand experiences are available. The economic and civic future of Maryland depends upon a substantial improvement in the quantity of students who meet Maryland's K-12 content standards and who successfully complete college or enter the workforce.

The focus on mathematics should promote mathematics as something important, something fun to do, something that will help you now and later in life, and something that makes sense. Such activities may include, but should not be limited to:

- Providing industry-sponsored internships/mentorships
- Providing speakers who will visit schools to discuss the importance of mathematics—as a career, in society, in sports, etc.
- Creating special programs such as "Discover E" for middle and high schools where engineers work directly with students and teachers in the classroom
- Supporting the appropriate use of mathematics contests and competitions
- Supporting programs where college faculty visit schools to discuss how mathematics may connect with a variety of majors and minors in higher education
- Participating in the Maryland MESA (Mathematics, Engineering, Science Achievement) program

Responsibility: *Local school systems, the Maryland State Department of Education, the Business Roundtable, Maryland Colleges and Universities, Maryland Partnership for Teaching and Learning K-12, and the Maryland Council of Teachers of Mathematics*

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23 **Provide opportunities to enlist the support of parents to help advocate mathematics learning.**

Rationale: Decades of research have shown that family involvement is critical to student achievement. Parents are a child's first teacher and continue to provide the incentive to learn throughout that child's educational career. Students are more successful in homes where parents provide an environment that encourages learning, communicate high expectations for achievement, and are involved in their child's education. A full partnership between parents and the schools will ensure the highest academic achievement.

Local schools systems can support parental involvement by:

- Providing access to materials for parents/community members (e.g., *Figure This!*, 1999)
- Providing models and materials for organizing a family math night or math Olympics at the elementary and middle school levels
- Supporting programs where various industries visit schools to discuss how mathematics may connect with a variety of professions
- Offering workshops to discuss activities that parents can do at home to reinforce the math strategy in schools
- Encouraging parent volunteers to consider roles as math mentors and/or tutors

Responsibility: *Local school systems*

24 **Regularly update principals and counselors on the importance and value of mathematics for all students at every level of instruction.**

Rationale: In order for changes to occur in our school systems, the focus on mathematics excellence needs to become ingrained in the culture of the system. It will not last long if it becomes just a program for a particular "focus" year. Maryland needs to rally its communities and keep this focus in the forefront, for a very long time. The Maryland State Department of Education should take the lead in coordinating and communicating what each school system is accomplishing in their local outreach campaigns. Only then will each school system be able to benefit from the successes of each of the other systems. By learning from each other, Maryland schools and school systems will be able to provide all students with an environment that promotes excellence in mathematics.

Responsibility: *Local school systems, the Maryland State Department of Education, and the Maryland Council of Teachers of Mathematics*

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Appendix

Maryland Assessment Profile

Maryland School Performance Assessment Program (MSPAP)

The Maryland School Performance Assessment Program (MSPAP) is a criterion-referenced testing program that assesses student knowledge of a well-defined set of Maryland Learning Outcomes. It measures higher-order thinking processes and the application of knowledge and skills to real world situations. MSPAP measures performance in a single performance test covering reading, writing, language usage, mathematics, science, and social studies for each student in grades 3, 5, and 8. The assessment, given during one week each spring, requires approximately nine hours of engaged testing time over five days.

Students receiving special education services may be exempted from MSPAP only when they are pursuing alternative or life skills outcomes (not Maryland Learning Outcomes). English as a Second Language (ESL) students may be exempted from one test administration if they do not have the minimum language proficiency required to be validly assessed using the MSPAP.

The satisfactory standard for schools and school systems is met when 70% or more of the students achieve at the satisfactory or above level; the excellent standard is met when 70% or more of the students achieve at the satisfactory or above level and 25% or more achieve at the excellent level. Only one Maryland school district (Kent County) has achieved satisfactory in any of the six content areas of MSPSP. This county has achieved the excellent standard in mathematics for grade 3 for the past three years.

Outcome Scale Scores for MSPAP

The outcome scale scores (scores between 350 and 700) for grades 3, 5, and 8 are listed below.

Note: Proficiency Level Cut-Off Scores are: Grade 3: 531; Grade 5: 520; Grade 8: 525

Table A1. Mathematics Learning Outcomes, 2000

	Grade 3	Grade 5	Grade 8
Communication	514	512	529
Reasoning	514	524	532
Connections	524	520	514
Number Concepts/Relationships	529	506	538
Measurement/Geometry	531	518	522
Statistics	519	515	521
Probability	522	511	529
Patterns/Algebra	527	523	538

Maryland State Department of Education, 2000

Maryland Functional Testing Program

The Maryland Functional Testing Program includes tests in the areas of reading, writing, and mathematics. The purpose of the Maryland Functional Testing Program is to ensure that students have acquired minimum levels of competency in basic skills or "functional" areas prior to leaving public education. Students must pass all tests as one condition for graduation from high school.

The Maryland Functional Mathematics Test (MFMT) is a criterion-referenced test that assesses student knowledge of 30 functional mathematics objectives. Although the functional tests have no time limits, the mathematics test takes approximately 90 minutes of engaged testing time. Computer-adaptive versions of the reading, mathematics, and citizenship tests take approximately 30 to 45 minutes. Maryland ninth-grade students have maintained a satisfactory standard (80% pass rate) in mathematics for the past six years with 2000 results of 85.1%. However, Maryland eleventh graders have never achieved the satisfactory standard of 97% in mathematics (96% in 2000).

Comprehensive Test of Basic Skills (CTBS/5)

The CTBS/5 provides norm referenced test information. The tests measure reading, language, language mechanics, mathematics, and mathematics skills, and they provide comparative information on the performance of Maryland students and students in national norming samples. Unlike the MSPAP and MFMT, there is no standard established for all students. Although CTBS addresses some of the same outcomes that are assessed on MSPAP, the formats of the tests are different. CTBS/5 uses only multiple choice responses while MSPAP uses constructed responses, both brief and extended.

In the spring of 1997, Maryland required the CTBS/5 to be given to a sample of at least 250 students per school system in each of grades 2, 4, and 6. Beginning with the spring of 2000, Maryland requires the CTBS/5 to be given to all students in grades 2, 4, and 6 each year. The total engaged testing time is approximately three hours for each student tested. From 1992 until 1995, Maryland required the CTBS/4 to be given in grades 3, 5, and 8; the CTBS/4 tests measured reading comprehension, language usage, and mathematics total. Maryland did not require a norm referenced assessment to be given in 1996. Because the CTBS/5 is based on a different national norming sample than the CTBS/4, results from the two assessments are not comparable.

National Assessment of Educational Progress (NAEP)

For over 30 years, the National Assessment of Educational Progress (NAEP) has reported to policy makers, educators, and the general public on the educational achievement of students in the United States. As the nation's only ongoing survey of students' educational progress, NAEP has become an important resource for obtaining information on what students know and can do in grades 4, 8, and 12 in reading, writing, mathematics, and science. NAEP results

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are reported according to three achievement levels: Basic, Proficient, and Advanced. The Basic level denotes partial mastery of prerequisite knowledge and skills that are fundamental for proficient work at each grade. The Proficient level represents solid academic performance and demonstrated competence over challenging subject matter. The Advanced level signifies superior performance.

According to the National Education Goals Panel (1998), Maryland's eighth grade students have improved in mathematics achievement but fourth graders have not improved. The panel reports that the percentage of Maryland's public school eighth graders who met the Goals Panel's performance standard (Proficient or Advanced) in mathematics increased from 17% in 1990 to 20% in 1992 to 24% in 1996. However, between 1992 and 1996, there was no significant change in the percentage of public school fourth graders who met the Goals Panel's performance standard in mathematics (18% in 1992 to 22% in 1996).

SAT

The SAT (formerly the Scholastic Aptitude Test) assesses mathematics and verbal skills. SAT scores range from 200 to 800. Scores prior to 1996 have been recentered for comparison purposes (College Board Seminars; 1998 Profile of SAT & Achievement Test Takers.) The national SAT mathematics mean score for high school seniors has increased from 503 to 514 over the past eight years. In Maryland, the mathematics scores have increased from 503 to 509 during the same time period. However, it should be noted that 65% of Maryland students take the SAT compared to 43% nationally.

Advanced Placement (AP)

The Advanced Placement Mathematics tests are criterion-referenced tests that assess student knowledge of a well defined set of college-level course objectives. Scores range from a high of 5 to a low of 1. Colleges generally give advanced placement and credit for scores of 3 or better. Students in Maryland who took the AP Calculus AB test scored on average 3.14 and BC students scored 3.42. Students who took the newest mathematics test, Statistics, scored 2.87. In Maryland, the percentage of students scoring a 3 or better on advanced placement exams was 71%. In Calculus AB, 66% scored 3 or better; in Calculus BC, 80% scored 3 or better; and in Statistics, 61% scored 3 or better.

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